Some Limitations and Errors in Current Turbine Noise Models

Limitations in modeling assumptions

Harvey Hubbard's paper, gives an overview of many of the assumptions made in Wind Turbine noise modeling

Wind Turbine Acoustics Harvey Hubbard.pdf

These assumptions are:

1. Incoherent addition is a sum of the random-phase multiple noise sources at any arbitrary receiver distance.

2. Each source radiates equally in all directions

3. Propagation is over flat, homogeneous terrain

4. That a logarithmic wind-speed gradient is present

Recent Findings that address these Limitations

Just like a map, isn't the territory, since it's not possible to include all the relevant information in a map.

Likewise a physical model is never the same as reality. If the assumptions are technically correct then the model can approach the results obtained in the real situation.

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Godefridus Petrus van den Berg

Godefridus Petrus van den Berg Thesis.zip

Day and Night Differences

"There is a distinct audible difference between the night and daytime wind turbine sound at some distance from the turbines. On a summer's day in a moderate or even strong wind the turbines may only be heard within a few hundred meters and one might wonder why residents should complain of the sound produced by the wind farm. However, in quiet nights the wind farm can be heard at distances of up to several kilometers when the turbines rotate at high speed. In these nights, certainly at distances from 500 to 1000 m from the wind farm, one can hear a low pitched thumping sound with a repetition rate of about once a second (coinciding with the frequency of blades passing a turbine mast), not unlike distant pile driving, superimposed on a constant broad band 'noisy' sound. A resident living at 1 km from the nearest turbine says it is the rhythmic character of the sound that attracts attention: beats are clearly audible for some time, then fade away to come back again a little later. A resident living at 2.3 km from the wind farm describes the sound as 'an endless train'. In daytime these pulses are usually not audible and the sound from the wind farm is less intrusive or even inaudible (especially in strong winds because of the then high ambient sound level). In the wind farm the turbines are audible for most of the (day and night) time, but the thumping is not evident, although a 'swishing' sound –a regular variation in sound level- is readily discernible. Sometimes a rumbling sound can be heard, but it is difficult to assign it, by ear, to a specific turbine or to assess its direction"

Predicting average sound levels is like predicting the average depth of a swimming pool. It tells you little about the risks involved.

In my experience it is the fact that stable environmental conditions at night produce increased wind at hub height, and increased noise which disrupt sleep. These conditions occur on clear starry night sand result in significant increases in the source sound power, increased tonality and sound fluctuations which are not represented in the manufacturers turbine sound power levels.. These are the frequently occurring worst case conditions that occur regularly in near wind turbines in rural communities

van den Berg shows that adjacent turbines cannot be treated as incoherence random-*phase sources in Stable Wind Conditions*

"In a stable atmosphere turbines in a wind farm can run almost synchronously because the absence of large scale turbulence leads to less variation superimposed on the constant (average) wind velocity at each turbine. In unstable conditions the average wind velocity at the turbines will be equal, but instantaneous local wind velocities will differ because of the presence of large, turbulent eddies at the scale of the inter turbine distance. In a stable atmosphere the turbulence scale decreases with a factor up to 10, relative to the neutral atmosphere and even more relative to an unstable atmosphere [Garratt 1992]. In stable conditions turbines in a wind farm therefore experience a more similar wind and as a consequence their instantaneous speeds are more nearly equal. This is confirmed by long term measurements by Nanahara et al. [2004] who analyzed coherence of wind velocities between different locations in two coastal areas. At night wind velocities at different locations were found to change more coherently than they did at daytime [Nanahara 2004]. The difference between night and day was not very strong, probably because time of day on its own is not a sufficient indicator for stability.1 The decay of coherence was strongly correlated with turbulence intensity, which in turn is closely correlated to stability.

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Thus several turbines can be nearly synchronous: sometimes two or more turbines are in phase and the blade passing pulses coincide, and then they go out of phase again causing beats.

The maximum error depends on the number of turbines, and how close to being in-phase they are. In a recent email George Kamperman pointed out "No turbine is more than 60 degrees out of phase with any other turbine. Yes you could in theory measure +6 dB (in phase) but no cancellation".

This is due to the fact that most of the periodic noises are generated as a blade passes the turbine support post. If they are close to speed synchronicity, as van den Berg has shown the maximum difference in timing between the turbines is ½ of the 120 degree spacing of the blades.

Assume the turbine reference sound power is 0db
For two equal ***incoherent*** turbines the total is increased by +3db
For two equal ***coherent*** turbines the total is increased by +6db
For four equal ***incoherent*** turbines the total is increased by +6db
For four equal ***coherent*** turbines the total is increased by +12db

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Some Limitations and Errors in Current Turbine Noise Models

Take for example 4 adjacent turbines ***rotating in close synchronicity***. The increase in sound power for coherent sources is of the order 20 log 4 or 12 db.

The increase for 4 adjacent turbines treated as ***random-phase not rotating in close synchronicity*** multiple noise sources is only +6db.

This is an increase not accounted for in the existing models

Clifford Schneider

Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at the Maple Ridge Wind Power Facility, Lowville, NY - 2007.pdf

New York State is currently on a "fast-track" for developing sources of renewable energy – the goal is renewable energy constituting 25% of all energy sold in New York by 2013.

At present there are six commercial wind farms operating in New York State, with four more under construction. There are another 30 projects that are under some stage of environmental review, and there are undoubtedly more that are being considered. There are a number of important issues that confront developers in getting their projects approved; one of them is dealing with wind turbine noise. Although wind farm noise may be low compared to a big municipal airport, in a quiet rural setting even low level noise can pose a significant problem. Wind power developers use mathematical models to predict the impact of wind turbine noise on nearby residents. However, no one knows if predicted noise impacts are high, low or on target. Developers, planning boards and residents are all assuming that model predictions are accurate and that they do not require any validation. ***Regrettably, there have been no compliance surveys done on any of the six operational wind farms in New York State.***

The main objective of this study was to measure the noise levels at two sites within Atlantic Renewable Energy Corporation's Maple Ridge Wind Power Project located in Lewis County, New York, and compare actual levels with the model predictions that were available in the preconstruction Draft Environmental Impact Statement (DEIS).

The second objective was to examine atmospheric stability at Maple Ridge. Atmospheric Stability was identified as a significant problem at a wind farm on the Dutch-German border. Stability occurs when ground level winds, where people live and reside, are decoupled from those at wind turbine hub-height. This can occur at the end of the day when the land mass begins to cool. It affects wind turbine noise because wind turbines can be operating and making noise when ground level winds are calm and we expect quiet surroundings.

This study demonstrated that ***summer, night-time noise levels*** exceeded levels predicted for two sites within the Maple Ridge Wind Farm. For winds above generator cut-in speed (e.g., 3.0 m/s @ 80-m), the **measured noise was 3-7 dBA above predicted levels.**

Measuring Background Noise clif Schneider Internoise 2009 .pdf

The decoupling of ground level winds from higher level winds, i.e., atmospheric stability, was apparent in the noise data at both sites during evening and night-time periods. At wind speeds below 3.0 m/s, when wind turbines were supposedly inoperative, noise levels were 18.9 and 22.6 dBA above the expected background levels for each of the sites and these conditions occurred a majority of the time. The same results were evident in the evening period. Furthermore, digital recordings revealed prominent wind turbines sounds below cut-in speeds. The fact that nearly all measurements exceeded Atlantic Renewable's predicted impacts suggests there is a problem with the choice of a model and/or how the models are configured. The model protocol used by Atlantic Renewable is very common; most wind power developers in New York use the same protocol. However, different models used in wind farm noise assessments have been shown to produce different results, and the model used by Atlantic Renewable was not designed to model elevated sources of sound, i.e., wind turbines.

In response to sound studies from commercial wind developers, a series of background noise surveys were conducted in Cape Vincent, NY between May and July 2008. The survey approach included sampling at night under stable atmospheric conditions and systematically selecting monitoring stations at 1.6 km intervals. ***Stable conditions occurred in 67% of nights*** and in 30% of those nights, wind velocities represented worst-case conditions where ground level winds were less than 2 m/s and hub-height winds were greater than wind turbine cut-in speed, 4 m/s. The median A-weighted L90A,9-hr sound pressure level was 25.7 dBA for five, fixed monitoring stations. For two mobile surveys, the medians (L90A,5-min) were comparable, 25.5 and 26.7 dBA.

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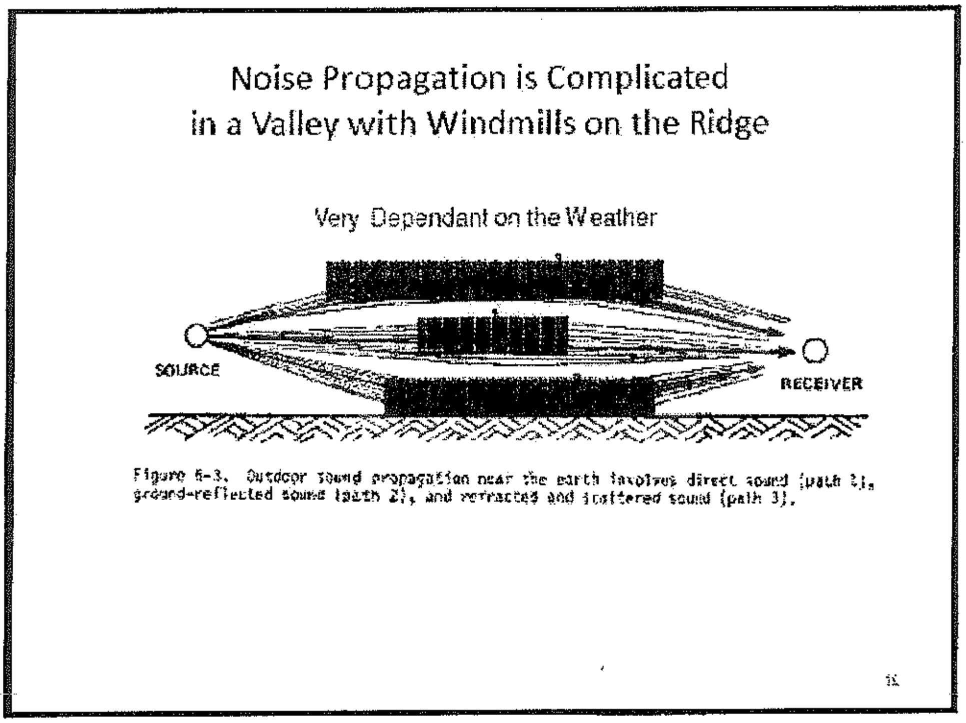
Extracts from a a presentation given in Allegheny, NY

weather_effects_on_noise_handout_ebbing.pdf

The refracted noise paths from the Turbines placed on ridge above a valley path is very dependent on the direction and wind speed versus height and is not a factor considered in the current computer models.

The ground reflected path includes the valley below which also involves refracted energy from the ridge turbines which directs additional sound to the valley below.



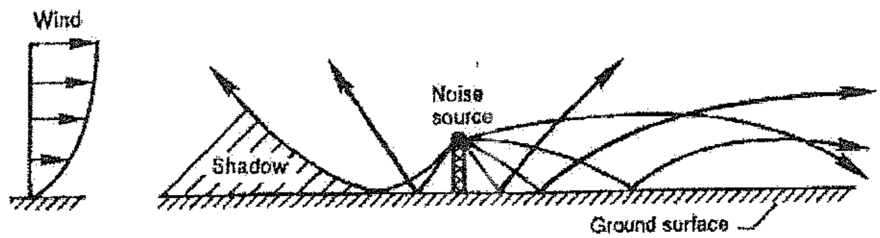
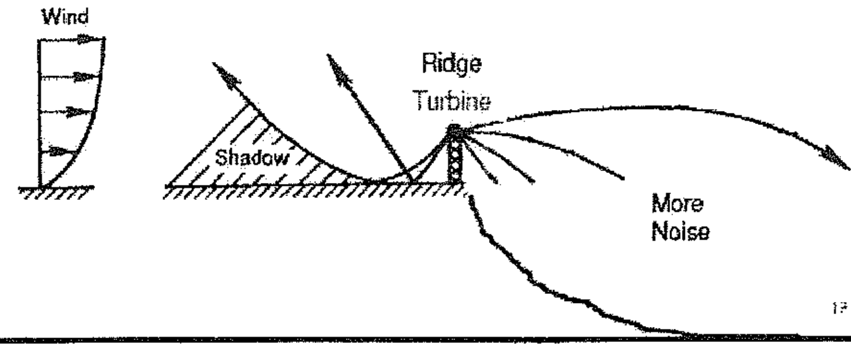


Figure 7-20. Effects of wind-induced refraction on acoustic rays radiating from an elevated point source [Shepherd and Hubbard 1985]



The upper figure taken from, ***Wind Turbine Acoustics Harvey Hubbard.pdf*** and illustrates that downwind of a turbine the sound rays are initially refracted downward and reflect off the adjacent level ground surface

When the turbines line the ridge as shown in the lower figure, wind velocity changes with height from the ground refracts much of the sound into the valley which is not included in the computer models.

Wind Turbines on Ridges
Some Thoughts

Teresa Drew and Roger Treagus, Golder Associates Ltd

- To account for noise, the site selection process needs to be broader than is often the case with other developments.
- ***Because sound carries farther downwind***, it's important to know both the ***dominant direction*** and how often the wind deviates from it.
- The minimum distance, or setback, from a "receptor" such as a farm house or subdivision (including those planned for the future) ***should be increased if it is frequently downwind of the wind farm.***
- A ***worst case wind direction analysis*** seems appropriate to determine if which operating conditions will have ***most impact on intrusive noise into the community*** and to control the operation of the wind farm appropriately.
- The ***topography and ground conditions can significantly affect noise*** propagation. Studies have shown that ***lining a ridge with turbines*** produces "shadow zones" on its slopes: ***noise levels are actually lower near the turbines than at a distance in the valleys below***. For sites near a body of water, remember that reflections off the water's surface can amplify noise.
- Sound ***level projections are more acceptable if they are based on real-world results.*** Developers need to conduct thorough preconstruction projections of a project's noise impacts and ***then verify them later***.

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Location, Location, Location,
An investigation into wind farms and noise by the Noise Association
John Stewart

- Mid Wales - a land of hills and valleys. A place where the wind blows frequently and the population tends to be thinly spread. Ideal for wind farms. And, not surprisingly, many are planned. ***The best place very often for the turbines to catch the wind is close to the top of a hill. It means that the wind turbines can be at their most productive.***
- ***But it also means that the noise may cascade down the surrounding valleys. To makes matters worse,*** **many** of the scattered hamlets within the valleys snuggle into corners protected by the hills and the mountains where the background noise level is very low indeed.
- **You only need to visit these areas to hear the 'swish, swish, swish' of the turbines – particularly downwind – over a mile away from the wind farm.**

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Mars Hill

- Mountainous typography especially ***arising from plains or rolling hills***, such as Mars Hill Ridge and its immediate surroundings, ***give rise to broadly varying atmospheric conditions over relatively short distances.***

- For example, ***vigorous ridgeline winds*** may be consistent with **up-wind low elevation surface conditions**, but be contrasted ***downwind at surface levels by light or even calm conditions.***

- Given these potential variations, ***upwind receptors*** would experience high level masking and "shadow" atmospheric refraction conditions minimizing ridgeline source sounds, whereas ***downwind receptors*** would ***experience minimal masking and atmospheric refraction lapse conditions that would enhance ridgeline source sounds.***

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Mars Hill

Calm surface conditions do not necessarily correlate with hub level wind speed. This is often seen in a neutral atmosphere in the evening and nighttime hours or downwind conditions on the leeward side of the ridge, when hub level wind speeds maybe considerable, but ***contrasting surface conditions are calm or light and variable.***

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Present computer models do not do an adequate job of modeling the case where noise predictions are made in the valley below. For these to be valid, the model used must be verified by showing the model results do indeed agree with an actual noise measurements within reasonable bounds for an array of turbines above a valley

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Wind Turbine Acoustics

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understood factors is the effect of the wind. Included here are brief discussions of the effects of distance from various types of sources, the effects of such atmospheric factors as absorption in air and refraction caused by sound speed gradients, and terrain effects.

Distance Effects

Point Sources

When there is a nondirectional point source as well as closely grouped, multiple point sources, spherical spreading may be assumed in the far radiation field. Circular wave fronts propagate in all directions from a point source, and the sound pressure levels decay at the rate of −6 dB per doubling of distance in the absence of atmospheric effects. The latter decay rate is illustrated by the straight line in Figure 7-18. The dashed curves in the figure represent increased decay rates associated with atmospheric absorption at frequencies significant for wind turbine noise.

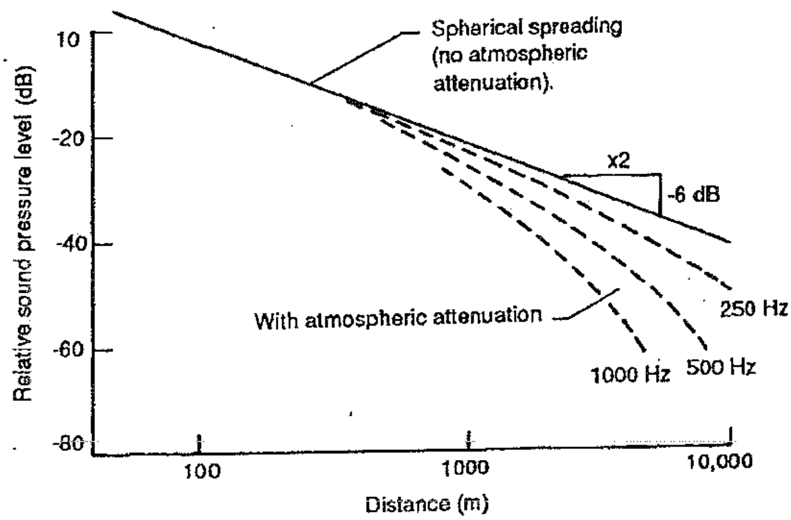

Figure 7-18. Decrease in sound pressure levels of pure tones as a function of distance from a point source [ANSI 1978]

Line Sources

For an infinitely long line source, the decay rate is only −3 dB per doubling of distance, compared with the −6 dB per doubling of distance illustrated in Figure 7-18. Such a reduced decay rate is sometimes observed for sources such as trains and lines of vehicles on a busy road. Some arrays of multiple wind turbines in wind power stations may also behave acoustically like line sources.

Atmospheric Factors

Absorption in Air

As sound propagates through the atmosphere, its energy is gradually converted to heat by a number of molecular processes such as shear viscosity, thermal conductivity, and molecular relaxation, and thus atmospheric absorption occurs. The curves in Figure 7-19 were plotted from ANSI values [1978] and show changes in atmospheric absorption as a function of frequency. In these examples, the ambient temperature varied from 0° to 20°C and the relative humidity varied from 30% to 70%. The atmospheric absorption is relatively low at low frequencies, increasing rapidly as a function of frequency. Atmospheric absorption values for other conditions of ambient temperature and relative humidity can be obtained from the ANSI tables; these values follow the general trend shown in Figure 7-19.

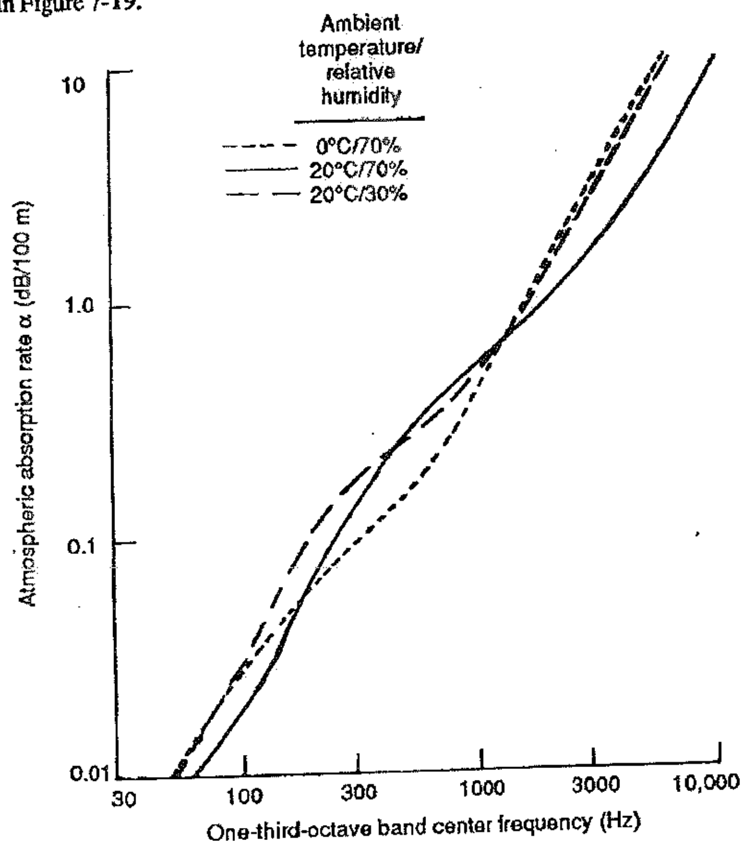

Figure 7-19. Standard rates of atmospheric absorption [ANSI 1978]

Refraction Caused by Wind and Temperature Gradients

Refraction effects arising from the sound speed gradients caused by wind and temperature can cause nonuniform propagation as a function of azimuth angle around a source. Figure 7-20 is a simple illustration of the effects of atmospheric refraction, or bending of

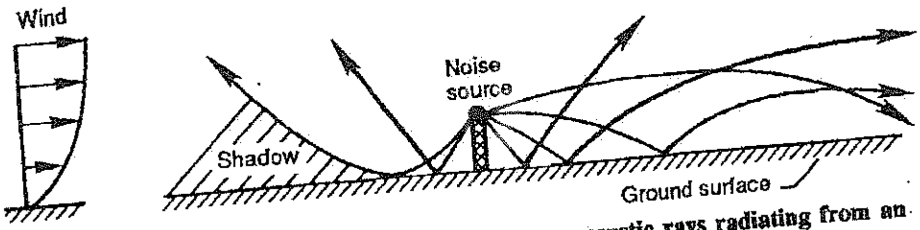

Figure 7-20. Effects of wind-induced refraction on acoustic rays radiating from an elevated point source [Shepherd and Hubbard 1985]

sound rays, caused by a vertical wind-shear gradient over flat, homogeneous terrain for an elevated point source. Note that in the downwind direction the wind gradient causes the sound rays to bend toward the ground, whereas in the upwind direction the rays curve upward away from the ground. For high-frequency acoustic emissions, this causes greatly increased attenuation in a shadow zone upwind of the source, but little effect downwind. The attenuation of low-frequency noise, on the other hand, is reduced by refraction in the downwind direction, with little effect upwind.

The distance from the source to the edge of the shadow zone is related to the wind-speed gradient and the elevation of the source. In a 10- to 15-m/s wind, for a source height from 40 to 120 m above flat, homogeneous terrain, the horizontal distance from the source to the shadow zone was calculated to be approximately five times the height of the source [Shepherd and Hubbard 1985].

Attenuation exceeding that predicted by spherical spreading and atmospheric absorption can be found in the shadow zone. This attenuation is frequency-dependent, and the lowest frequencies are the least attenuated. Figure 7-21 presents an empirical scheme for estimating attenuation in the shadow zone, based on information in Piercy, Embleton, and Sutherland [1977]; SAE [1966]; and Daigle, Embleton, and Piercy [1986]. The estimated

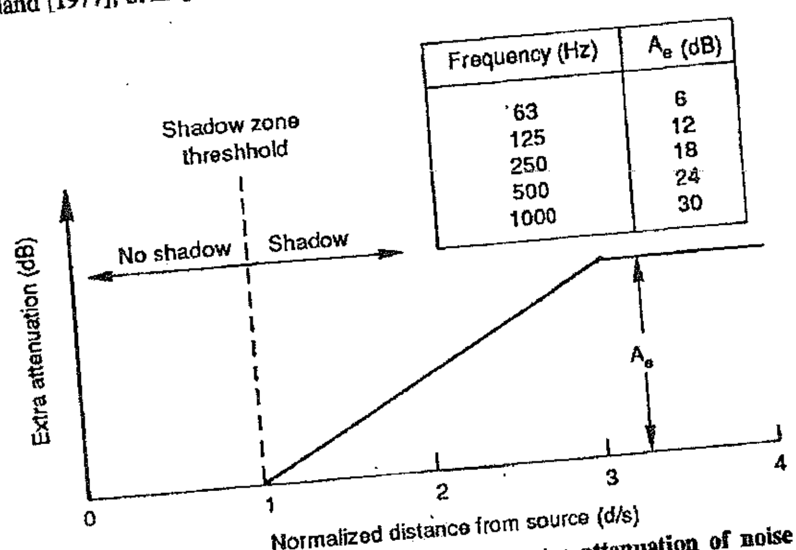

Figure 7-21. Empirical model for estimating the extra attenuation of noise in the shadow zone upwind of an elevated point source (s = 5h, 40 ≤ h ≤ 120 m, where h = source elevation) [Shepherd and Hubbard 1985]

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extra attenuation (A_e in Figure 7-21) is assumed to take place over a distance equal to twice that from the source to the edge of the shadow zone. The predicted decay in the sound pressure level from the source to the edge of the shadow zone is caused by atmospheric absorption [ANSI 1978] and spherical spreading. Within the shadow zone, extra attenuation should be added as estimated according to Figure 7-21.

Note that vertical temperature gradients, which are also effective sound speed gradients, will normally also be present. These will add to or subtract from the effects of wind that are illustrated in Figure 7-21. Effects of wind gradient will generally dominate those of temperature gradients in noise propagation from wind power stations.

Distributed Source Effects

Because of their large rotor diameters, some wind turbines exhibit distributed source effects relatively close to the machines. Only when listeners are at distances from the turbines that are large in relation to the rotor diameter does the rotor behave acoustically as a point source. As indicated in Figure 7-22, distributed source effects are particularly important in the upwind direction. In this figure, sound pressure levels in the 630-Hz, one-third-octave band are presented as a function of distance in the downwind, upwind, and crosswind directions. The measured data agree well with the solid curves, which represent spherical spreading and atmospheric absorption in the downwind and crosswind directions. In the upwind direction, however, the measured data fall below the solid curve; this

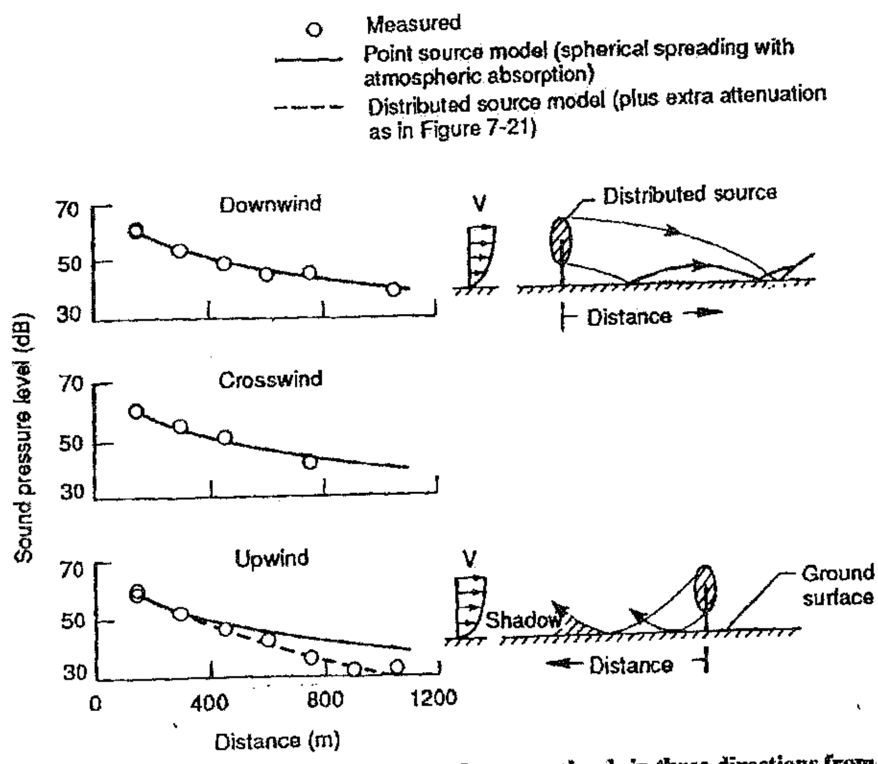

Figure 7-22. Measured and calculated sound pressure levels in three directions from a large-scale HAWT (one-third-octave band = 630 Hz, rotor diameter = 78.2 m) [Shepherd and Hubbard 1985]

indicates the presence of a shadow zone. An improvement in predicting upwind sound pressure levels is obtained when the noise source is modeled as being distributed over the entire rotor disk. Each part of the disk is then considered to be a point source, and attenuation is estimated by means of the empirical model shown in Figure 7-21. The resulting predictions are shown as the dashed curve of Figure 7-22 and are in good agreement with the sound measurements upwind of the turbine. In the downwind and crosswind directions, point-source and distributed-source models result in identical calculations of sound pressure levels.

Channeling Effects at Low Frequencies

Figure 7-23 illustrates the special case of propagation of low-frequency rotational-harmonics when the atmospheric absorption and extra attenuation in the shadow zone are very small. Measured sound pressure levels are shown as a function of distance for both the upwind and downwind directions. For comparison, the curves representing decay rates of −6 dB and −3 dB per doubling of distance are also included. Note that in the upwind case the sound pressure levels tend to follow a decay rate of −6 dB per doubling of distance, which is equal to the rate for spherical spreading. No extra attenuation from a shadow zone was measured.

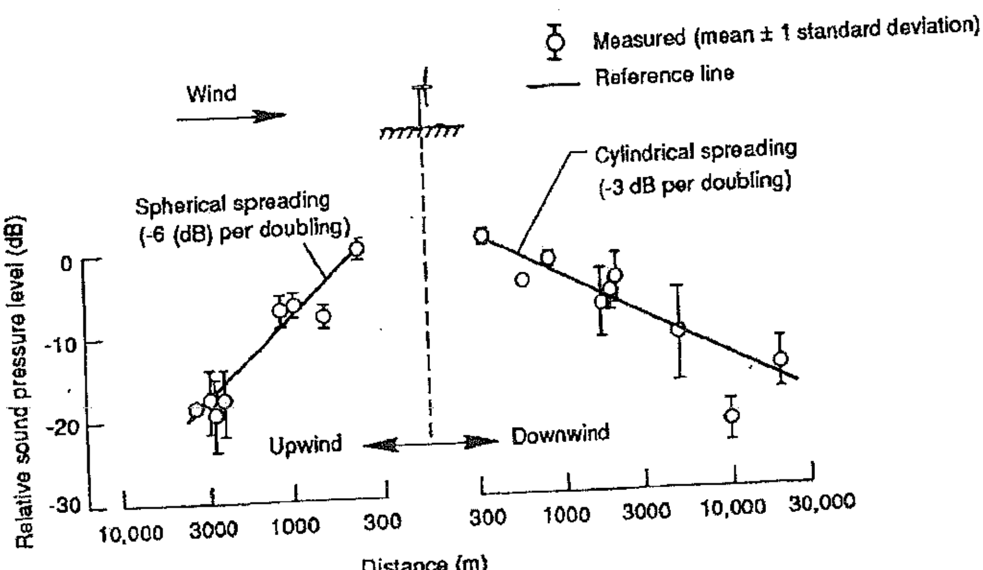

Figure 7-23. Measure effect of wind on the propagation of low-frequency rotational harmonic noise from a large-scale HAWT (harmonics with frequencies from 8 to 16 Hz, rotor diameter = 78.2 m) [Willshire and Zorumski 1987]

In the downwind direction, the sound pressure levels tend to follow a decay rate of −3 dB per doubling of distance, similar to that for cylindrical spreading. This reduced decay rate in the downwind direction at very low frequencies is believed to result from atmospheric refraction, which introduces a channeling sound path in the lower portions of the earth's boundary layer [Willshire and Zorumski 1987; Thomson 1982; Hawkins 1987].

Terrain Effects

Terrain effects include ground absorption, reflection, and diffraction. Furthermore, terrain features may cause complex wind gradients, which can dominate noise propagation to large distances [Kelley *et al.* 1985; Thompson 1982]. Wind turbines are generally located in areas devoid of trees and other large vegetation. Instead, ground cover usually consists of grass, sagebrush, plants, and low shrubs, which are minor impediments to noise propagation except at very high frequencies. At frequencies below about 1000 Hz, the ground attenuation is essentially zero.

Methods are available for calculating the attenuations provided by natural barriers such as rolling terrain, which may interrupt the line of sight between the source and the receiver [Piercy and Embleton 1979]. However, very little definitive information is available regarding the effectiveness of natural barriers in the presence of strong, vertical wind gradients. Piercy and Embleton [1979] postulate that the effectiveness of natural barriers in attenuating noise is not reduced under conditions of upward-curving ray paths (as would apply in the upwind direction) or under normal temperature-lapse conditions. However, under conditions of downward-curving ray paths, as in downwind propagation or during temperature inversions (which are common at night), the barrier attenuations may be reduced significantly, particularly at large distances.

Predicting Noise from Multiple Wind Turbines

Methods are needed to predict noise from wind power stations made up of large numbers of machines, as well as for a variety of configurations and operating conditions. This section reviews the physical factors involved in making such predictions and presents the results of calculations that illustrate the sensitivity of radiated noise to various geometric and propagation parameters. A number of valid, pertinent, simplifying assumptions are presented. A logarithmic wind gradient is assumed, with a wind speed of 9 m/s at hub height. Flat, homogeneous terrain, devoid of large vegetation, is also assumed. Noises from multiple wind turbines are assumed to add together incoherently, that is, in random phase.

Noise Sources and Propagation

Reference Spectrum for a Single Wind Turbine

The most basic information needed to predict noise from a wind power station is the noise output of a single turbine. Its noise spectrum can be predicted from knowledge of the geometry and operating conditions of the machine [Viterna 1981; Glegg, Baxter, and Glendinning 1987; Grosveld 1985], or its spectrum can be measured at a reference distance. Figures 7-9 and 7-10 are examples of spectral data for HAWTs. Also shown in Figure 7-10 is a hypothetical spectrum used in subsequent example calculations to represent a HAWT with a 15-m rotor diameter and a rated power of approximately 100 kW. The example spectrum is the solid line with a decrease of 10 dB per decade in sound pressure level with increasing frequency. This spectral shape is generally representative of the aerodynamic noise radiated by wind turbines. However, predictions for a specific wind power station should be based, if possible, on data for the particular types of turbines in the station.

Directivity of the Source

Measurements of aerodynamic noise for a number of large HAWTs (for example, Kelley *et al.* [1985]; Hubbard and Shepherd [1982]; and others listed in the bibliography) indicate that the source directivity depends on specific noise-generating mechanisms. For broadband noise sources, such as inflow turbulence and interactions between the blade boundary layer and the blade trailing edge, the sound pressure level contours at close distances are approximately circular. Lower-frequency, impulsive noise, which results when the blades interact with the tower or central column wake, radiates most strongly in the upwind and downwind directions.

Although there is one prevailing wind direction at most wind turbine sites, it is not uncommon for the wind vector to vary 90° in azimuth angle during normal operations. Therefore, one of the simplifying assumptions made in the calculations that follow is that each individual machine behaves like an omnidirectional source.

Considerations for Frequency Weighting

A-weighted sound pressure levels, expressed in dB(A), are in widespread use in evaluating the effects of noise on communities [Pearsons and Bennett 1974]. Figure 7-24 shows the results of applying this descriptor. The assumed single-turbine reference spectrum, at a distance of 30 m from the machine, is reproduced from Figure 7-10 as the solid line. The equivalent A-weighted spectrum at the same distance is shown as the upper dashed curve. This particular weighting emphasizes the higher frequencies and deemphasizes the lower frequencies according to the sensitivity of the human ear. As distances increase, as illustrated in the other dashed curves, atmospheric absorption causes the levels of the higher-frequency components to decay faster than those of the lower frequencies (see Figure 7-19). The result is that the midrange frequencies (100 to 1000 Hz) tend to dominate the A-weighted spectrum at large distances. Frequencies higher than 1000 Hz will generally not be important considerations at large distances because of the effects of atmospheric absorption. Frequency components below about 100 Hz may not be

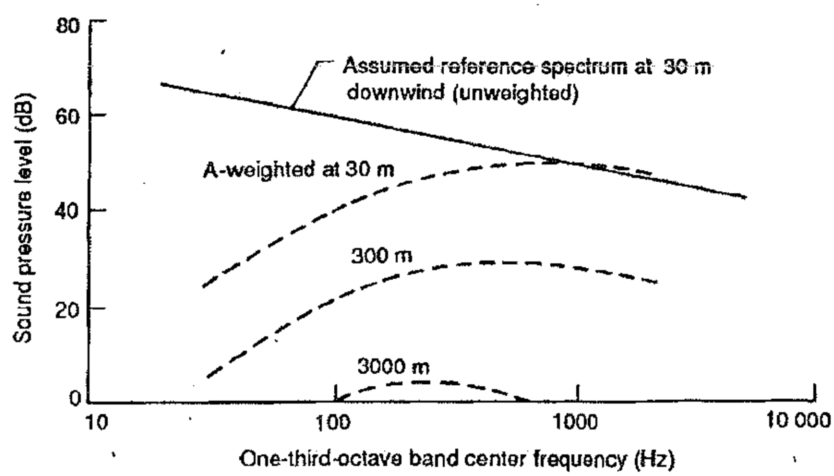

Figure 7-24. Reference and A-weighted noise spectra from a 15-m-diameter HAWT with a rated power of 100 kW (assumed for example calculations of noise from a wind power station)

significant in terms of audible noise, but they can be significant in terms of such indirect effects as noise-induced building vibrations.

Arrangement of Wind Power Stations

A basic geometric arrangement of wind turbines was assumed to represent an example wind power station (shown in Figure 7-25). The station consists of 31 turbines per row. Each machine produces approximately 100 kW of power, and the rotor diameter is 15 m. The spacing between turbines is 30 m, the row length is 900 m, and the spacing between rows is 200 m. The basic four-row configuration in Figure 7-25 was perturbed to investigate the effects of such variables as the number of rows, row and turbine spacing, row length, and turbine power rating.

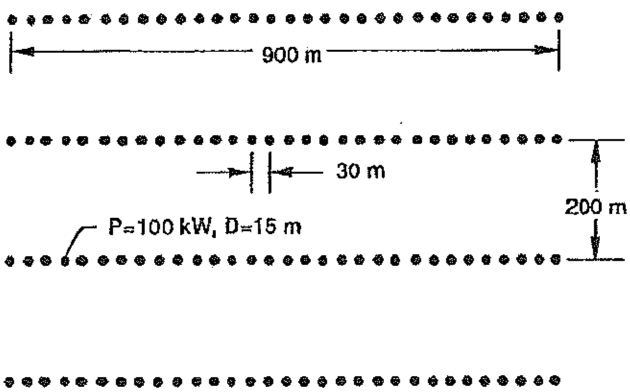

Figure 7-25. Layout of wind turbines in the example wind power station [Shepherd and Hubbard 1986]

Absorption and Refraction

These example calculations assumed an ambient temperature of 20°C and a relative humidity of 70%. From the data in Figure 7-19, assumed values of atmospheric absorption of 0, 0.10, 0.27, and 0.54 dB per 100 m correspond roughly to one-third-octave band center frequencies of 50, 250, 500 and 1000 Hz, respectively, for these temperature and humidity conditions. These frequencies were chosen because they encompass the range of frequencies considered important in evaluating the perception of wind turbine noise in adjacent communities [Shepherd and Hubbard 1986].

Calculation Methods

The method presented here for calculating the sound pressure level from incoherent addition is a sum of the random-phase multiple noise sources at any arbitrary receiver distance. This method assumes that each source radiates equally in all directions. Attenuation caused by atmospheric absorption is included; propagation is over flat, homogeneous terrain; and there is a logarithmic wind-speed gradient. The method has no limitations on the number of wind turbines or their geometric arrangements. The required input is a reference sound-pressure-level spectrum $L_o(f)$, either narrow-band or one-third-octave band, for a single wind turbine. This spectrum can be measured or predicted for a reference distance from the rotor hub of approximately 2.5 times the rotor diameter.

The sound pressure level received from an individual wind turbine in the array in a given frequency band can be calculated with the following equation:

$$L_n(f_i) = L_o(f_i) - 20\log_{10}(d_n/d_o) - \alpha(d_n - d_o)/100 \tag{7-8}$$

where

$L_n(f_i)$ = sound pressure level from the nth wind turbine (dB)
n = wind turbine index (1, 2, . . ., N)
N = number of wind turbines in the array
f_i = center frequency of the ith band (Hz)
$L_o(f_i)$ = reference sound pressure level in the ith frequency band from a single wind turbine at the reference distance (dB)
d_n = distance from the nth turbine to the receiver (m)
d_o = reference turbine-to-receiver distance (m)
α = atmospheric absorption rate (dB per 100 m)

The total sound pressure level, from all wind turbines in the array in the ith frequency band, is then calculated as follows:

$$SPL_{tot}(f_i) = 10\log_{10}\sum_n 10^{L_n(f_i)/10} \tag{7-9}$$

This procedure can be repeated for all frequency bands to provide a predicted spectrum of sound pressure level at the receiver location. Noise measures such as the A-weighted sound pressure level may also be calculated by adding the A-weighting corrections at each frequency to the values of $L_n(f_i)$ or $SPL_{tot}(f_i)$ in Eqs. 7-8 and 7-9. If the sources are arranged in rows, the required computations can be reduced by using the simplified procedures of Shepherd and Hubbard [1986].

Examples of Calculated Noise for Wind Power Stations

A series of parametric calculations of unweighted sound pressure levels was performed based on the array of Figure 7-25 and systematic variations of that array [Shepherd and Hubbard 1986]. The receiver is assumed to be on a line of symmetry either in the downwind, upwind, or crosswind direction.

Effect of Distance from a Single Row

Figure 7-26 shows calculated sound pressure levels for one row of the example wind power station, as a function of downwind distance for various rates of atmospheric absorption. Also shown are reference decay rates of –3 dB and –6 dB per doubling of distance. For an atmospheric absorption rate of zero, the decay rate is always less than that for a single point source (Figure 7-18). At intermediate distances, the row of turbines acts as a line source, for which the theoretical decay rate is –3 dB per doubling of distance or –10 dB per decade of distance. Only at distances greater than one row length (900 m) does the decay rate approach the single-point-source value of –6 dB per doubling of distance (–20 dB per decade). Decay rates increase as the absorption coefficient increases.

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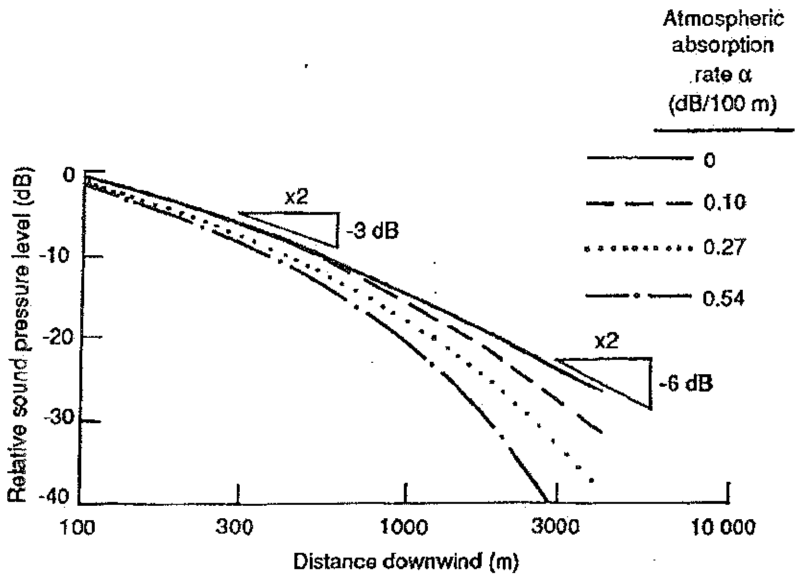

Figure 7-26. Calculated noise propagation downwind of a single row of wind turbines in the example array for four atmospheric absorption rates [Shepherd and Hubbard 1986]

Effect of Multiple Rows

Figure 7-27 presents the results of sound-pressure-level calculations that were made for one, two, four, and eight rows of wind turbines; this illustrates the effects of progressively doubling the number of machines for a constant turbine spacing. At zero atmospheric absorption, and at receiver distances that are large relative to the array dimensions, a doubling of the number of rows results in an increase of 3 dB in the sound pressure level.

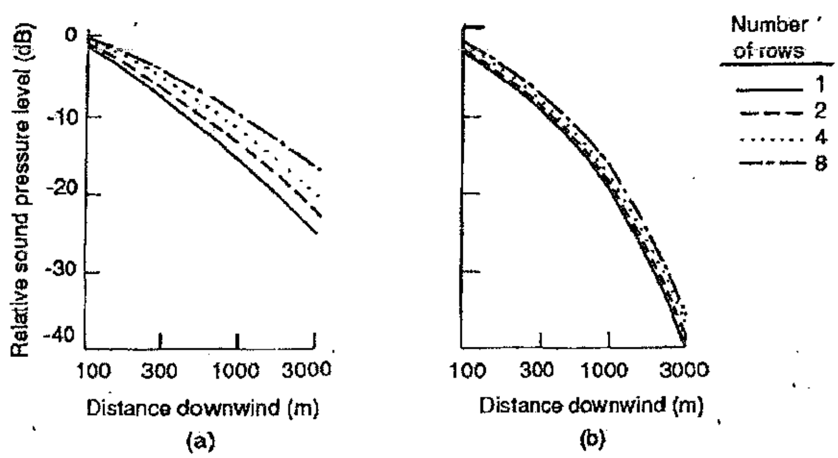

Figure 7-27. Calculated noise propagation downwind of various numbers of rows of wind turbines in the example array [Shepherd and Hubbard 1986]. (a) without atmospheric absorption. (b) $\alpha = 0.54$ dB/100 m.

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This simply reflects a doubling of acoustic power. At shorter distances, the closest machines dominate and the additional rows result in only small increments in the sound pressure level.

For nonzero atmospheric absorption, the effect of additional rows is less significant at all receiver distances. Doubling the number of rows results in an increase in the sound pressure level of less than 3 dB.

Figure 7-28 shows similar data for two different row lengths. For these comparisons, the turbine spacing is constant and the row lengths are doubled by doubling the number of machines per row. When the receiver is at shorter distances, the predicted sound pressure levels are equal because of the equal turbine spacing. At longer distances, the levels for the double-length row are higher by 3 dB because the acoustic power per row is doubled.

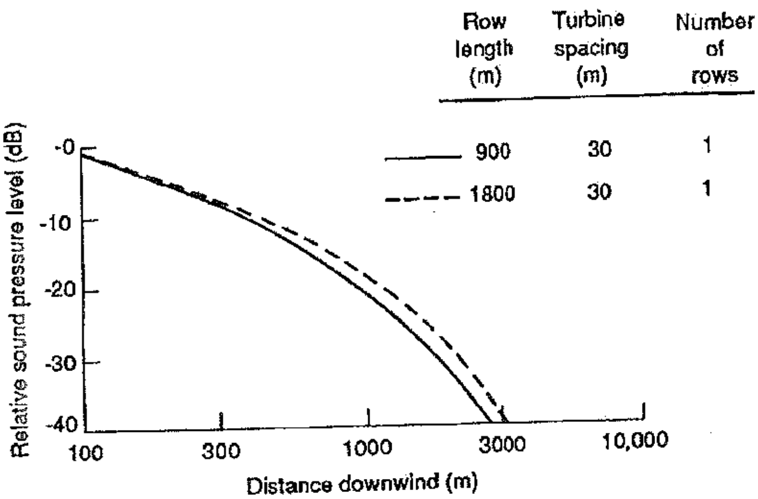

Figure 7-28. Calculated noise propagation downwind of wind turbines in rows of two different lengths (α = 0.54 dB/100 m) [Shepherd and Hubbard 1986]

Computations were also made [Shepherd and Hubbard 1986] for a configuration similar to that of Figure 7-25, except that the row spacing was reduced from 200 m to 100 m. At all distances to the receiver, the computed sound pressure levels were higher for this more compact array.

Effect of Turbine Rated Power

Shepherd and Hubbard [1986] calculate the effect of the turbine's rated power on noise emissions by increasing the power of each turbine and the total station power. The turbine and row spacings were adjusted from those of Figure 7-25 to more appropriate values for larger machines (four times the rated power). Sound pressure levels from rows of 16 400-kW wind turbines were compared with levels from the same number of rows of 31 100-kW machines. This approximately doubled the rated power of the station. The reference spectrum for the larger turbines was assumed to have the same shape as that of the smaller turbines (Figure 7-10), although the levels were all 6 dB higher. This implies four times the acoustic power for four times the rated power. The computed sound pressure levels are 3 dB higher for the array of larger turbines because the acoustic power is doubled for each row of the array. Different results would be obtained if the reference spectra of the two sizes of turbines had different shapes.

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APPLIED ACOUSTICS HANDBOOK

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The Directivity Factor (Q) is used to account for the presence of nearby reflectors. The sound pressure level (Lp) from an omnidirectional sound source of sound power level (Lw) in a free field can be estimated using the following relationship. The way in which reflecting planes affect the Directivity Factor is illustrated in Figure 2.2.

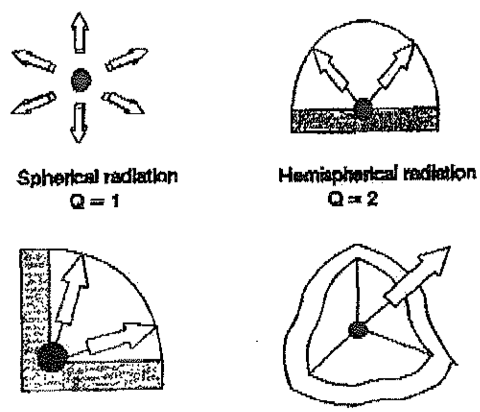


Figure 2.2 - Directivity Factor Depends on Nearby Reflecting Surfaces

CALCULATING SOUND PRESSURE FROM SOUND POWER IN A FREE FIELD

$$Lp = Lw + 10\ Log_{10}(Q/4\pi r^2) + 10.5 \qquad (2.2)$$

where:

Q	=	Directivity factor Q = 0, no reflecting planes present (free field) Q = 2, 1 reflecting plane present (free field above reflecting plane) Q = 4, 2 reflecting planes present (free field with one reflecting wall) Q = 8, 3 reflecting planes present (free field with source in corner of 3 perpendicular planes)
r	=	distance from acoustic center of the source to the estimation point (ft)
π	=	3.141593
Lw	=	sound power level (dB)
Lp	=	sound pressure level (dB)

POINT AND LINE SOURCES

POINT SOURCES

A point source is a sound source whose largest dimension is small in relation to the wavelength it is radiating. An example is a propeller fan of 3 ft. diameter that is radiating noise at 80 Hz (wavelength = 1100/80 = 13.75 ft). Because the fan is small in relation to the radiated wavelength, it can be considered a point source at 80 Hz.

SPREADING LAW

Point sources of sound produce equal sound radiation in all directions. The sound pressure level in a free field (no nearby significant reflecting surfaces) decreases by 6 dB each time the distance from a point source is doubled (Equation 2.3). This effect is sometimes referred to as the inverse square spreading law.

$$dB_1 - dB_2 = 20 \; Log_{10}(r_1/r_2) \qquad (2.3)$$

where:

dB_1	=	sound pressure level at distance r_1 (dB)
dB_2	=	sound pressure level at distance r_2 (dB)
r1	=	first distance from point source, ft
r2	=	second distance from point source, ft

As an example, if we are 10 ft away from the geometric center of a point source that measured 80 dB in a free field and we move to 20 ft away, the sound will be 6 dB less or 74 dB. Similarly, if we move double the distance again to 40 ft away, then the level will be 68 dB.

Figure 2.3 shows that the area over which the sound wave is spread varies by the area of the sphere and is proportional to the radius squared.

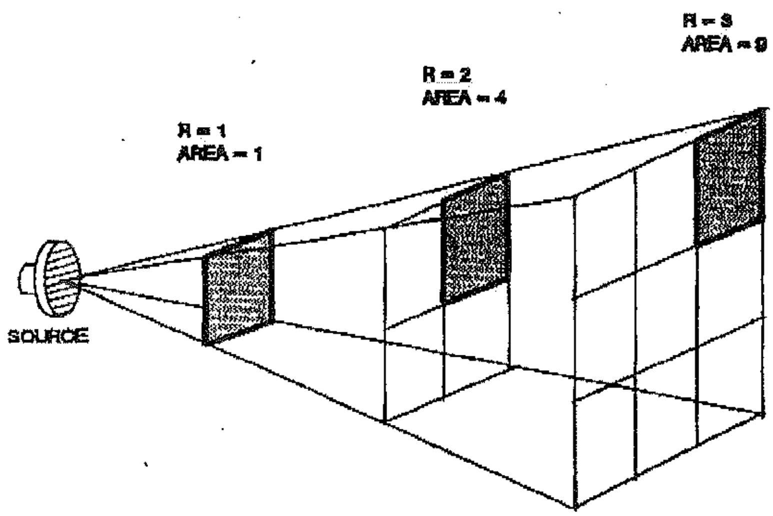


Figure 2.3 - The Spreading of Sound Energy With Distance

LINE SOURCES

A line source is a sound source composed of many point sources arranged next to each other in a line.

Line sources of sound produce equal sound pressures at equal distances perpendicular to the axis of the line source, out to a distance of approximately L/π, where L is the length of the line source. This happens because, initially, the wave fronts are cylindrical and the energy spreads in only one direction rather than in two directions, as with a point source. At distances greater than L/π, a line source starts to behave like a point source. At this distance the resulting wave fronts are more like spheres than cylinders.

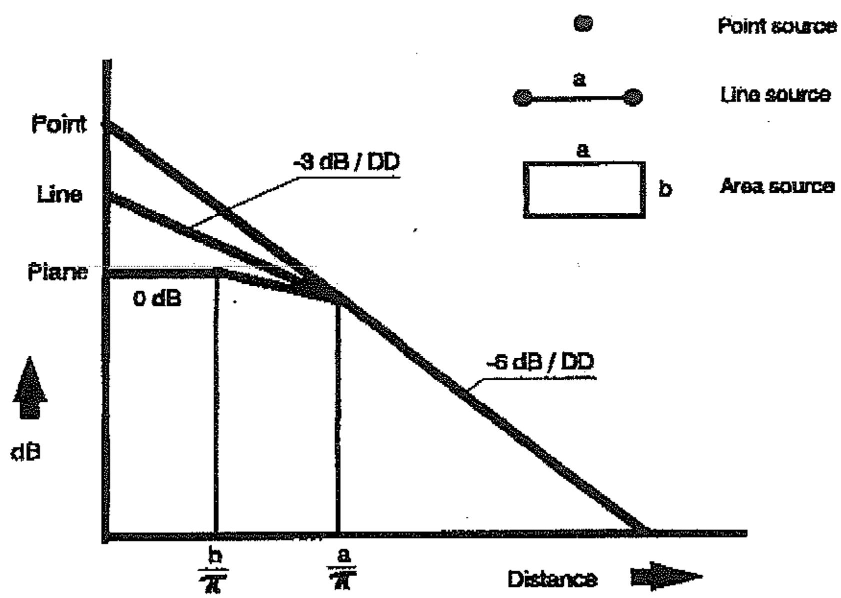
In the region where cylindrical spreading takes place, sound pressure drops off 3 dB each time the distance is doubled from a line source (Equation 2.4).

$$dB_1 - dB_2 = 10 \text{ Log}10(r_1/r_2) \tag{2.4}$$

where:

dB_1 = sound pressure level at distance r_1 (dB)
dB_2 = sound pressure level at distance r_2 (dB)
r1 = first distance from point source
r2 = second distance from point source

Figure 2.4 illustrates the falloff of sound pressure level from point, area and line sources.



Falloff from point and area noise sources

Figure 2.4 - Point, Area, and Line Sources

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Sound propagation from wind turbines

Mats Åbom

KTH - The Marcus Wallenberg Laboratory for Sound and Vibration Research

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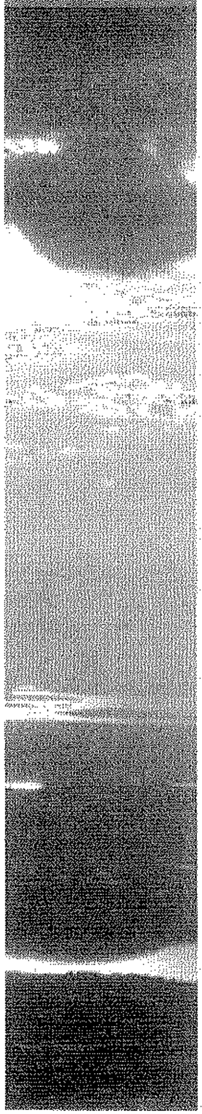
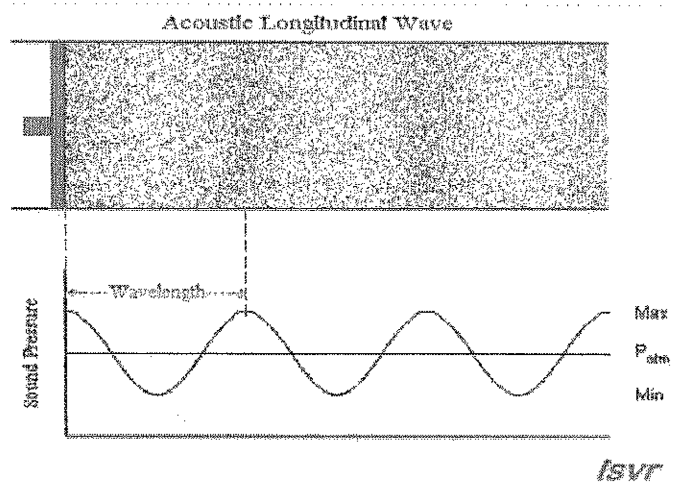


Presentation outline

- Some basic concepts
- Sound generation from windturbines
- Sound propagation in the atmosphere
- Masking by wind induced noise
- Measurements at Kalmarsund
- Summary and Conclusions

Some basic concepts

- Sound is elastic waves in gases, liquids or solids
- The waves represent small oscillations around an equilibrium, e.g., in the atmosphere around the equilibrium pressure 100 kPa.



- The human ear will detect sound in the frequency range 20-20 kHz
- The smallest level a human ear can detect is around 20 μPa and the highest around 100 Pa
- To better relate sound pressures p to the human reponse a logarithmic scale is used

$$L_p = 10 \cdot \log \frac{\tilde{p}^2}{p_{ref}^2} \; , [\mathrm{dB}]$$

where p_{ref} is 2×10^{-5} Pa

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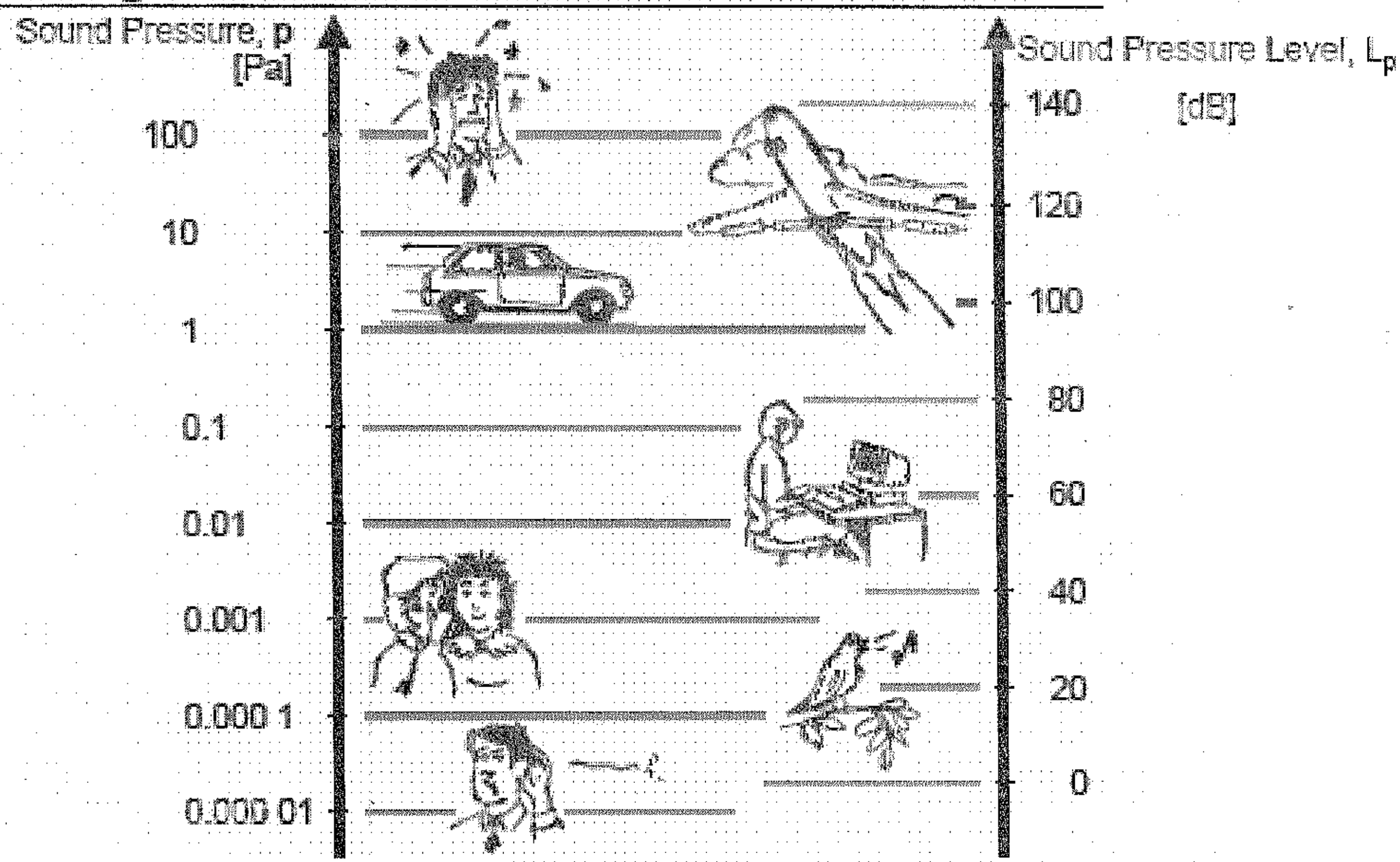
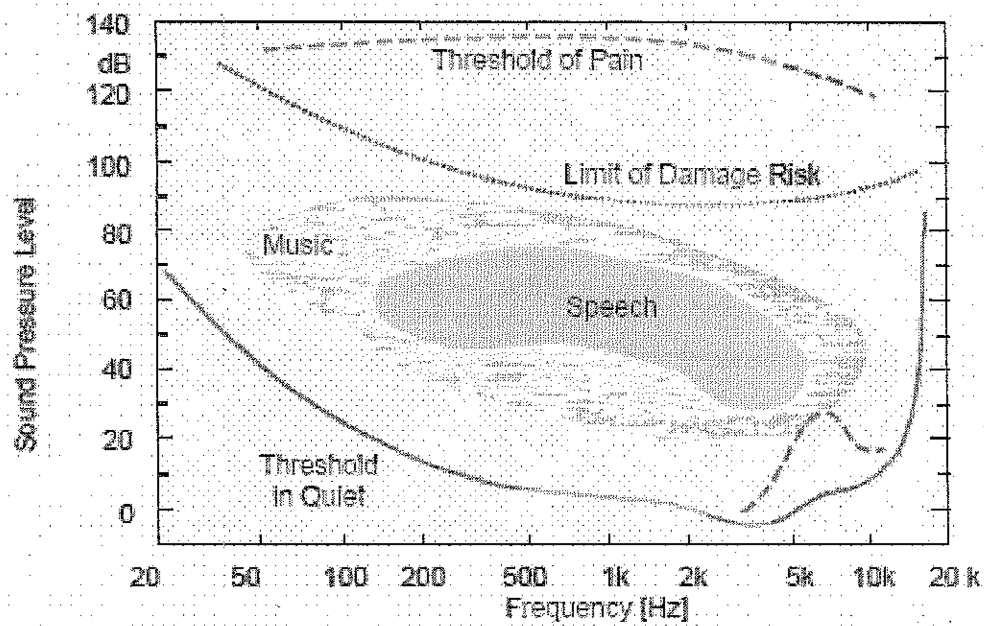
Range of Sound Pressure Levels



- The human ear has a sensitivity that varies with both frequency and amplitude.
- This is handled by using various weighting filters A-, B- and C- when sound is measured



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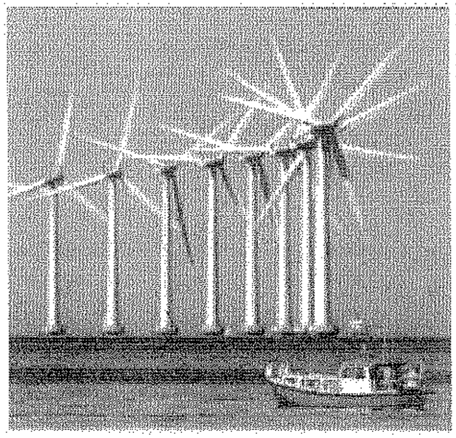
- *NOISE* - is unwanted sound that is disturbing or annoying
- Noise always involves a subjective assessment of the sound since everyone responds differently to sounds
- The most common measure to describe noise exposure is dB(A)
- For wind turbines the allowed average level is 40 dB(A)

Sound generation from wind turbines



- Noise can be created from gear boxes and the blades (aerodynamic)
- It is the unsteady aerodynamic forces on the blades that create sound

- The aerodynamic sound has two parts:
  a tonal part ($f0 < 20$ Hz) and a broadband part
- At short distances (< 0.5 km) amplitude modulation due to wind gradients can occur

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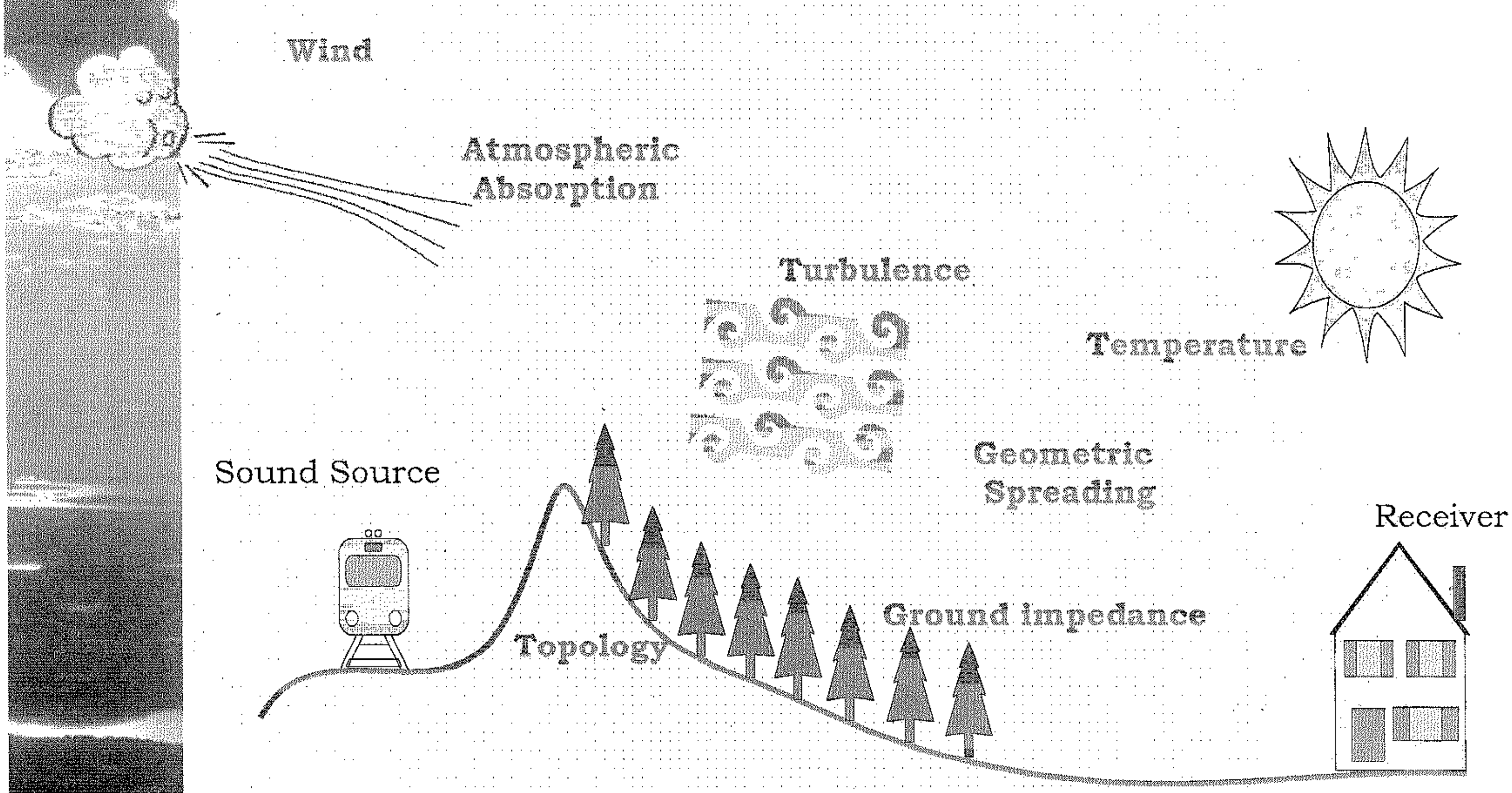
Sound propagation in the atmosphere



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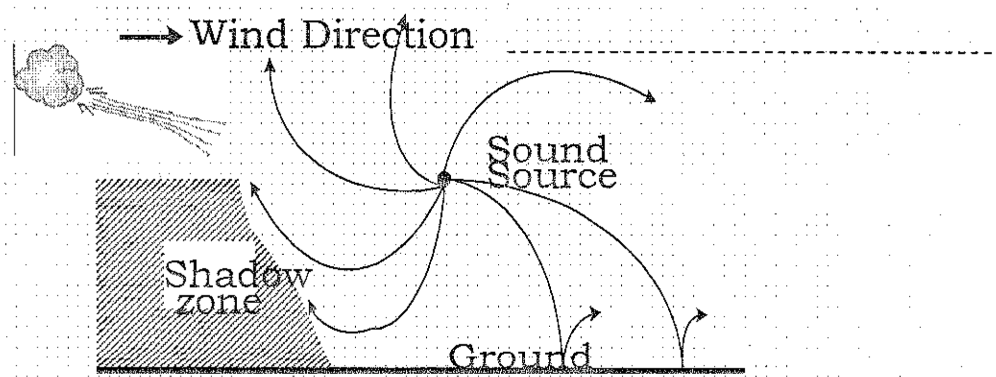
- Sound is always transmitted better in the down wind direction



- Instead of spherical wave (3D) spreading this leads to a cylindrical (2D) type of spreading
- Cylindrical spreading gives a reduced damping with distance. For each dubbling of distance we only get 3 dB reduction instead of 6 dB for spherical spreading

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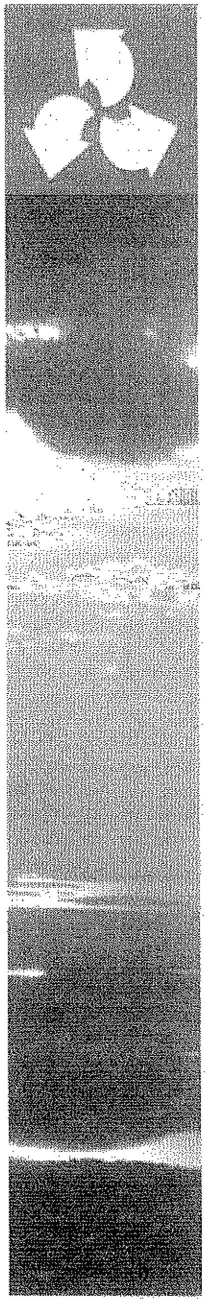
- For propagation over soft ground ("grass land") the reflections gives an extra damping
- This added damping will on the average in the down wind restore a behaviour close to a spherical damping
- BUT for propagation over hard surfaces as the sea, rocky terrain or desserts the ground damping is small
- This is the reason why in Sweden the Environmental protection Agency has recommended (report no. 6241) the use of cylindrical spreading for distances larger than 200 m for off-shore wind turbines

Sweden uses Line sources



Masking by wind induced noise

- In a KTH PhD project (MASK) the masking of wind turbine noise by vegetation and sea waves are studied
- The work has resulted in a validated model for vegetation noise (Tech. Lic. thesis by Karl Bolin Nov. 2006)
- For masking it was found by Karl B that a 3 dB S/N ratio is required

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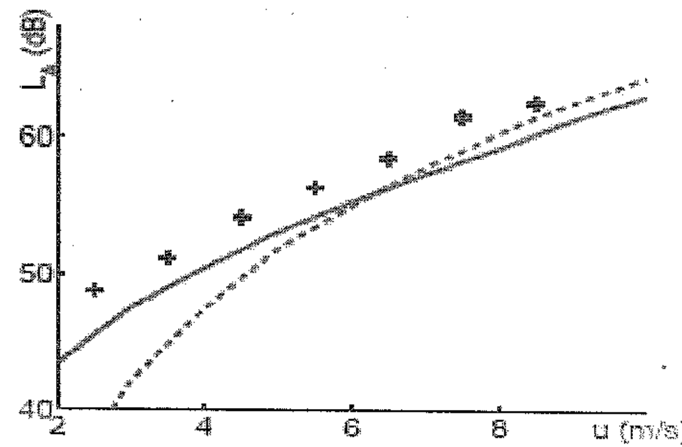

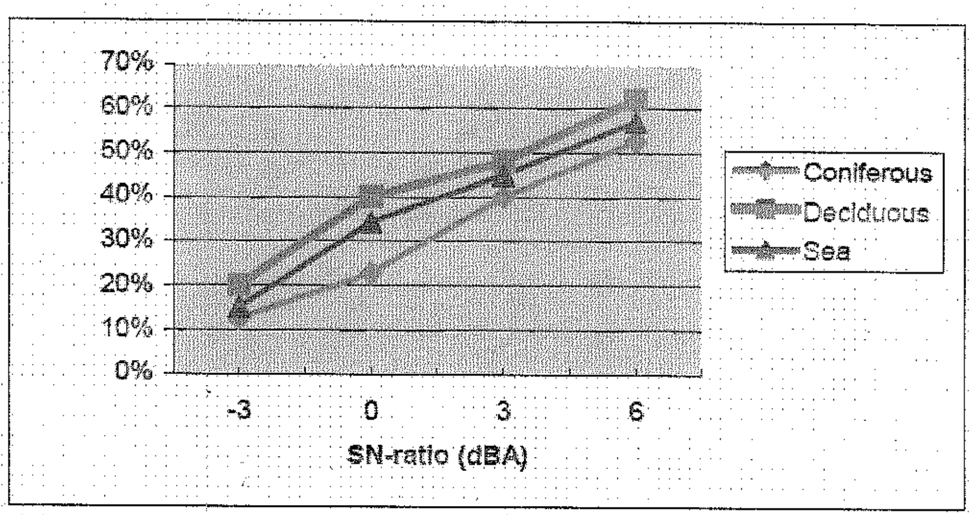

Measurements at Kalmarsund

Objectives (Project TRANS)

- To develop techniques for long range measurements of sound transmission
- To apply the techniques to study the occurence of cylindrical wave spreading
- To couple the occurence of cylindrical wave spreading to meteorological phenomena e.g. low level jets (LLJ)
- To test the validity of the recommendation to apply cylindrical spreading for distances larger than 200 m for off-shore wind

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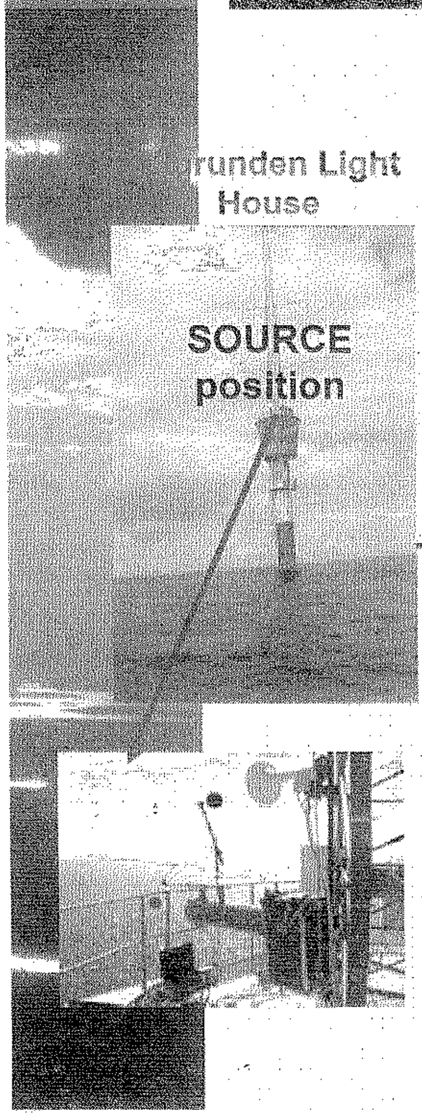
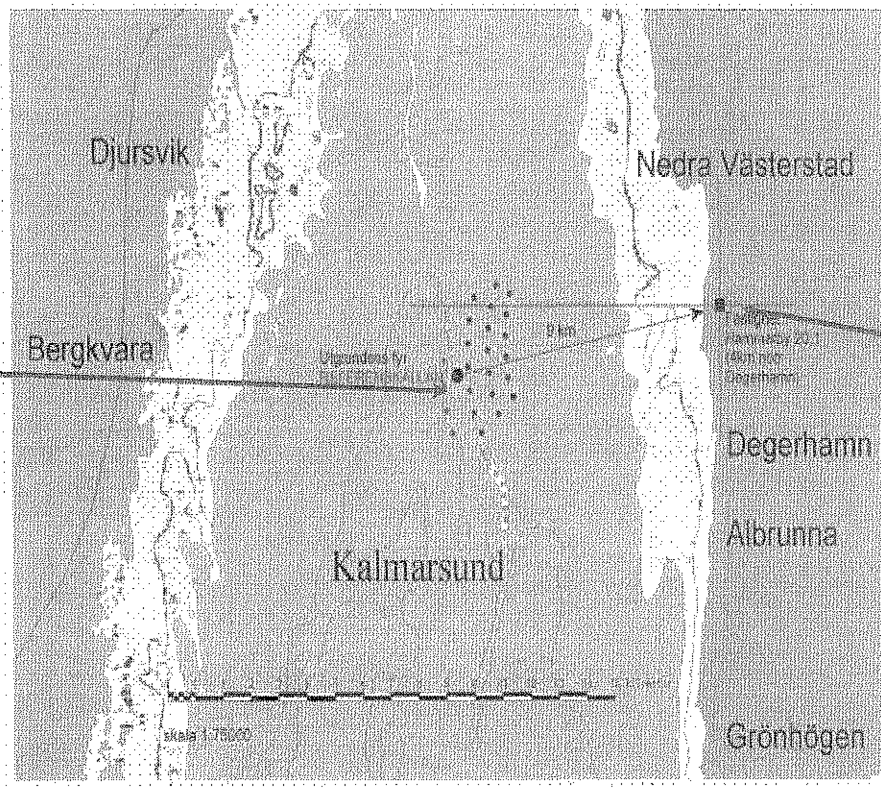
Measurement site and set-up

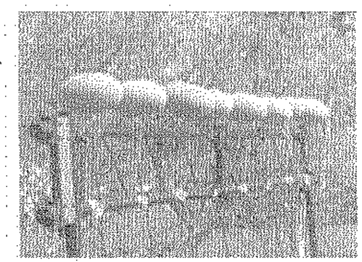
runden Light
House





Hammarby at
island Öland

RECEPTION
Position with a
microfone array



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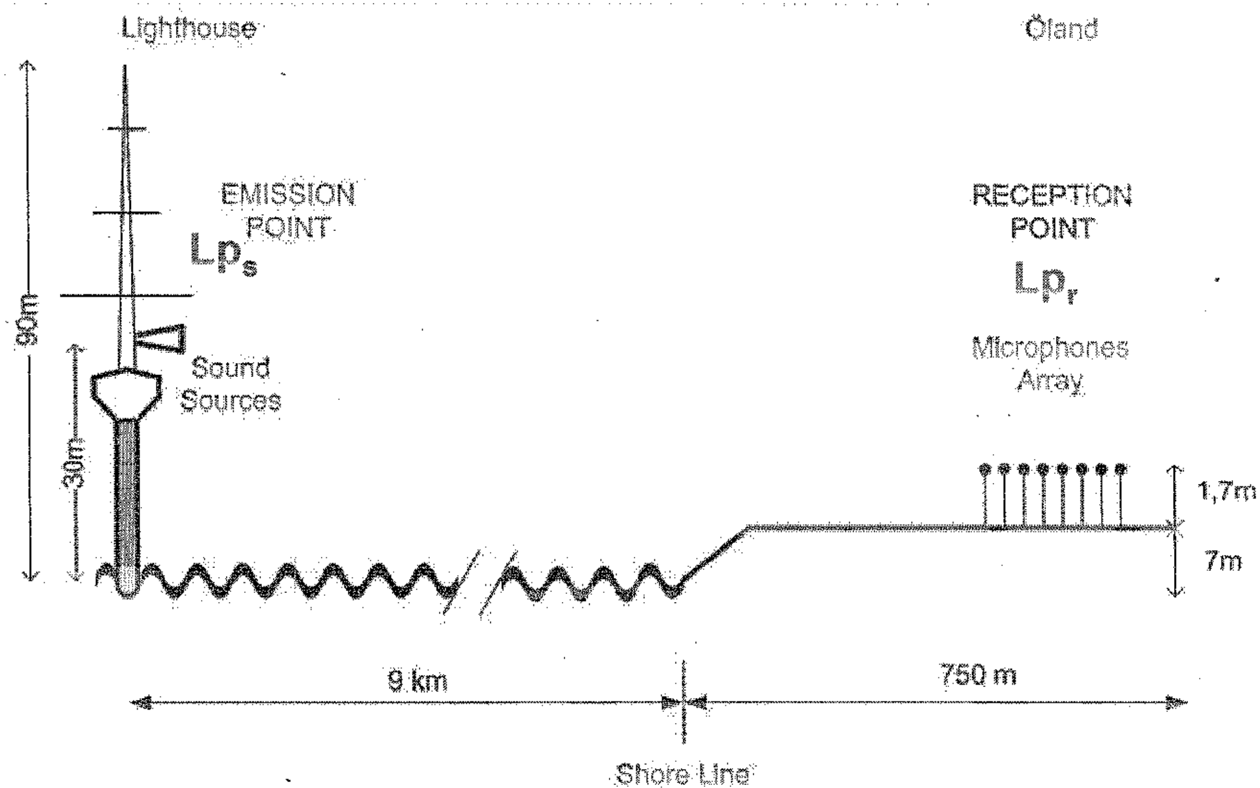

Meteorological data (wind speed/temperature/humidity) was recorded at the Lighthouse.

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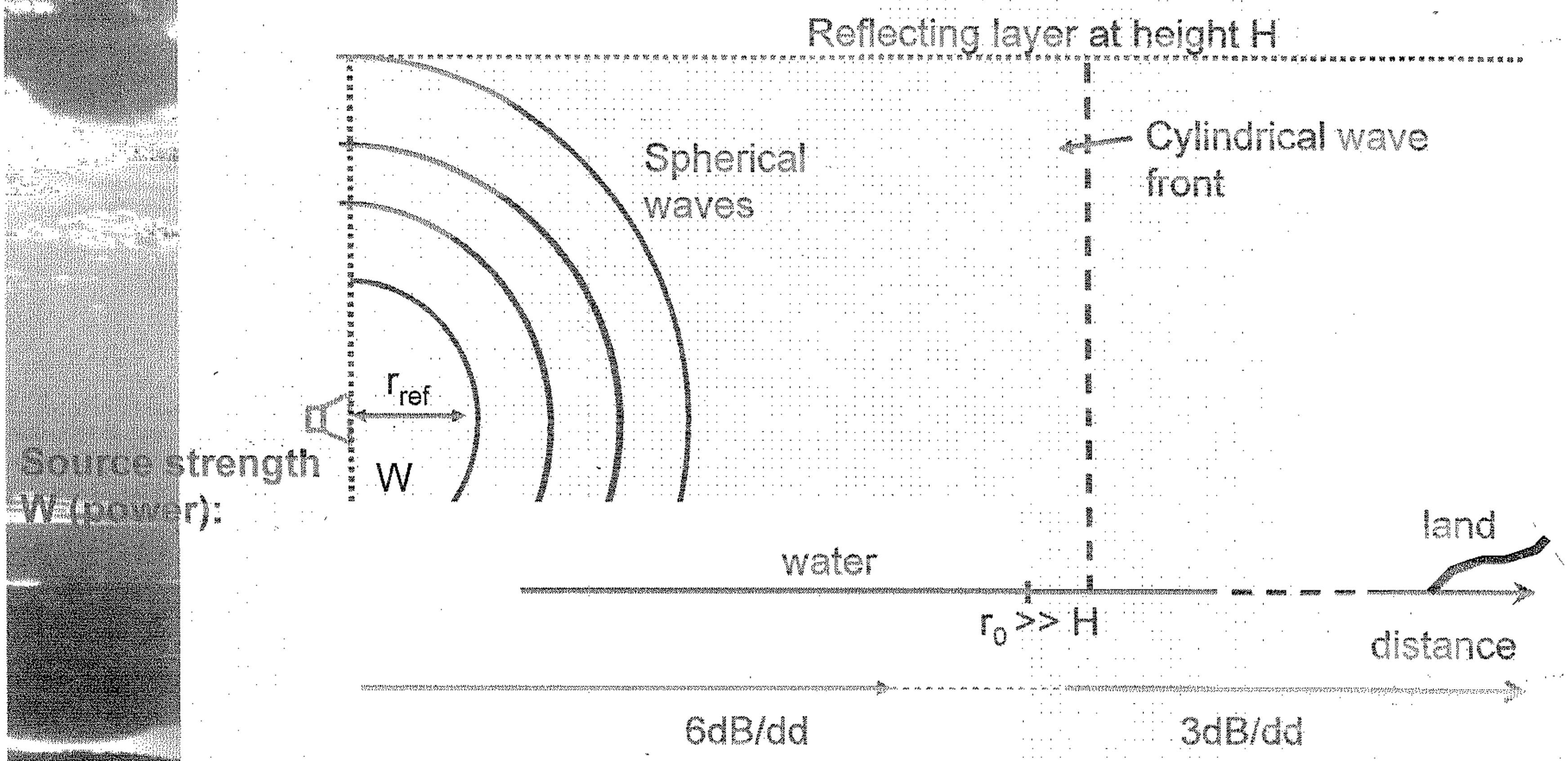
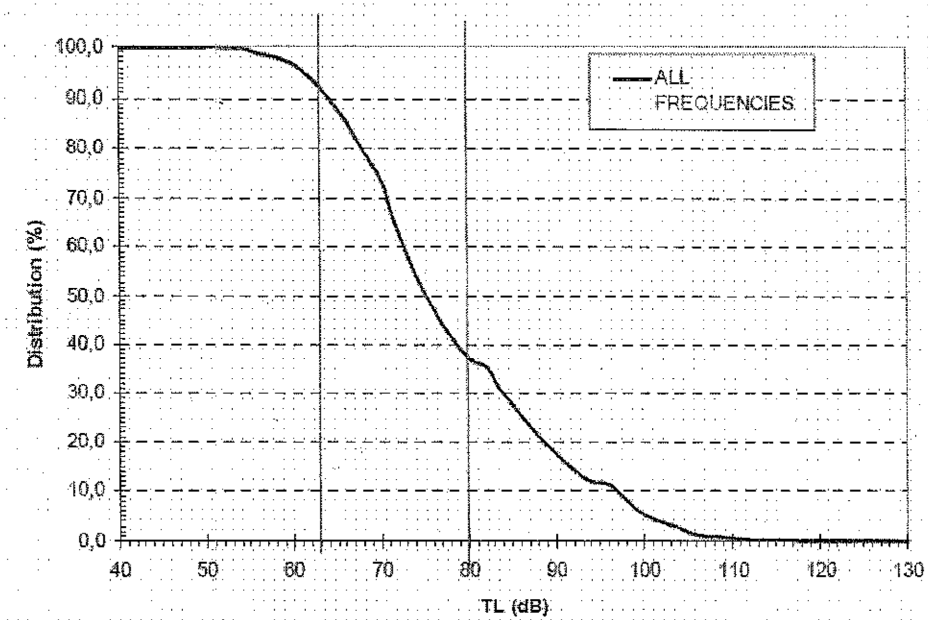
Transition Spherical - Cylindrical



Damping due to wave spreading based on data at 80 Hz, 200 Hz and 400 Hz



The red lines at 63 dB and 80 dB corresponds to cylindrical and spherical wave spreading respectively.

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Results - Summary

Data from Utgrunden June 2005/2006	80 Hz	200 Hz	400 Hz	All frequencies
Average TL = $10\log_{10}\left(\frac{1}{N}\sum_n 10^{-TL_n/10}\right)$ [dB]	70	67	67	68.4
TL_{10} [dB]	97	94	95	97
TL_{90} [dB]	65	62	62	64

The expected Transmission Loss with the model recommended by the Swedish Environmental Protection Agency is for this case = 63 dB. This value deviates significantly from the observed average 68 dB but is close to the TL90 value for our data.

Summary and Conclusions

- Sound propagation from wind turbines is strongly affected by the meteorological conditions

- Reduced damping over areas with hard surfaces e.g. the sea can be expected. Because the ground damping occuring for soft surfaces (e.g. grass land) does not exist

- Wind induced noise from vegetation and sea waves can be effective in masking wind turbine noise (Tech. Lic thesis K. Bolin KTH 2006)

- The occurrence of cylindrical wave spreading in Kalmarsund has been investigated by KTH

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- Based on data taken under June 2005/2006 it is found that cylindrical wave spreading on the average occurs after a distance of 700 meters

- This result indicates that the recommendation by the Swedish Environmental Protection Agency (report no. 6241) to apply cylindrical wave spreading after 200 meters for off-shore wind turbines is too strict

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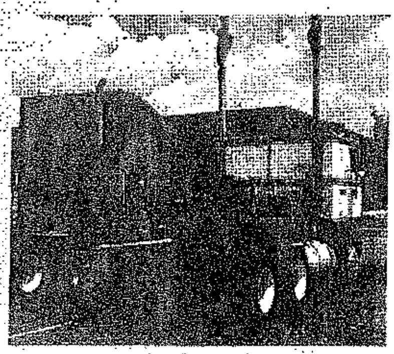
Technical Assistance Bulletins

Noise



A technical assistance series prepared by:

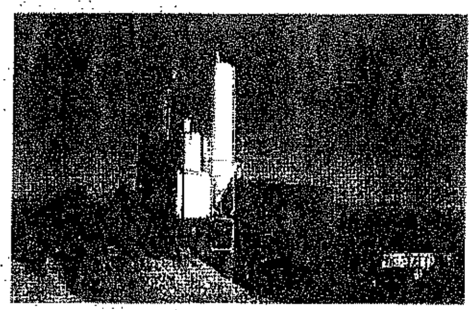
Maine State Planning Office

Maine Department of Environmental Protection

Oxford County Soil and Water Conservation District

Androscoggin Valley Council of Governments

with input from a number of professional and citizen planners.



Inside

TA Bulletin #4

This TA Bulletin is one in a series of documents intended to provide guidance to volunteer board and committee members on specific planning topics. Emphasis is placed on the development review process.

Financial assistance for the development of this document provided by the National Oceanic and Atmospheric Administration.

May 2000

Introduction

Noise has significant environmental impacts even though it is a transient occurrence. It does not accumulate in the environment, but its impacts can be long lasting affecting people's lives and property values. Noise causes a deterioration in the quality of life as much as, if not more than, many other environmental problems.

Noise standards can only be effective when the limitations and enforcement procedures are easily implemented.

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Background Information

Importance of Noise and Noise Control

Prolonged noise exposure is a serious threat to human health; it can result in high stress levels and, at high sound levels, impaired hearing. Common environmental noise sources can cause or contribute to stress-related illnesses such as cardiac and circulatory diseases. Noise can also negatively impact concentration, communication, and sleep creating annoying and sometimes even hazardous conditions. These factors are important in setting noise standards for the community. It may be important to protect certain uses such as offices, schools, and churches from significant noise increases to allow effective communication. It is also important to protect neighborhoods so that residents can communicate and enjoy their property. Residential areas should also be protected from noise so that residents are able to obtain uninterrupted sleep. Interrupted sleep can result in serious health impacts and also affect personal safety at home and at work. Another consideration for municipal officials is property values. Neighborhoods subject to noise disturbance will generally have lower values.

Principles of Noise

Noise travels in waves through the air. It has three components: intensity, frequency, and duration. The disturbance caused by noise is not just related to intensity, which we commonly call "loudness," but it also depends on the frequency (or pitch) and the duration (or how long the noise lasts).

- **Intensity**, the sound level, is actually the sound pressure level (SPL): the pressure that sound waves exert as they ~~travel through the air. It is measured in decibels (dB) on~~ a logarithmic scale. This means that a sound of 60 dB is not twenty percent (20%) louder than one of 50 dB, it is ten (10) times (one thousand percent [1,000%]) louder. (Fortunately, the human ear does not perceive it as that great of an increase.)

- **Frequency** (not how often the sound occurs but the frequency of the sound wave) is measured in hertz (Hz) and is the number of cycles per second of a sound wave. The "pitch" of a sound is directly related to the frequency. Most noise covers a range of frequencies, but a concentration in a narrow frequency band, such as a whistle, is more bothersome than a mix of sounds across a wide range of frequencies.

- **Duration** is the length of time the sound lasts. Intermittent sounds (such as back up horns) are typically more annoying than steady ones (such as the hum of a motor). To account for the length of time that noises last, many noise standards use an equivalent sound level, although this adds complexity to measurements which may need to be taken. The equivalent sound level "averages" the sound level over a given period of time, typically one (1) minute or one (1) hour.

For most municipal standards, noise is measured using a scale weighted to account for the higher frequencies to which the human ear responds. It is called the A-weighting scale and is noted by the abbreviation dBA. It is also measured in sound level equivalents (designated Leq). Sound levels often vary over time. The Leq is the equivalent constant sound energy to that emitted by the varying sound over a given period of time, usually one (1) hour.

The following table provides some examples of typical sounds.

COMMON SOUND LEVELS

Sound Environment	Sound Pressure Level (dBA)
Threshold of hearing	0
Broadcast studio interior or rustling leaves	10
Quiet house interior or rural nighttime	20
Quiet office interior or watch ticking	30
Quiet rural area or small theater	40
Quiet suburban area or dishwasher in next room	50
Office interior or ordinary conversation	60
Vacuum cleaner at 10 ft.	70
Passing car at 10 ft. or garbage disposal at 3 ft.	80
Passing bus or truck at 10 ft. or food blender at 3 ft.	90
Passing subway train at 10 ft. or gas lawn mower at 3 ft.	100
Night club with band playing	110
Threshold of pain	120

There are some important characteristics about noise and noise measurement which must be kept in mind. An important principle is experienced daily; noise varies with distance. It is much louder close to the source than it is at a distance. Therefore, the standard must identify the **sound level limit** and the **location** at which the limit is applicable.

In addition to the three (3) components (intensity, frequency, and duration), the time of day that the noise occurs also contributes to the degree of disturbance and its impacts. Nighttime noise is more annoying than daytime noise and may cause more noticeable health impacts through the disruption of sleep. Thus, most standards provide a daytime criteria and a nighttime criteria, although the time periods vary from one municipality to another and may even vary by zone within a municipality.

To account for tonal noises (noises having a narrow frequency band), many standards add a fixed decibel equivalent to the measured noise level in order to account for the additional annoyance such a sound causes. This is also true for repetitive noises. (Repetitive noises are those noises which are generally of a short duration, but which occur at regular intervals such as a back-up horn on construction vehicles.)

Due to the logarithmic nature of noise measurement and the way noise levels are perceived by humans, care must be taken in using absolute limits. The following table provides some typical human perceptions of noise increases.

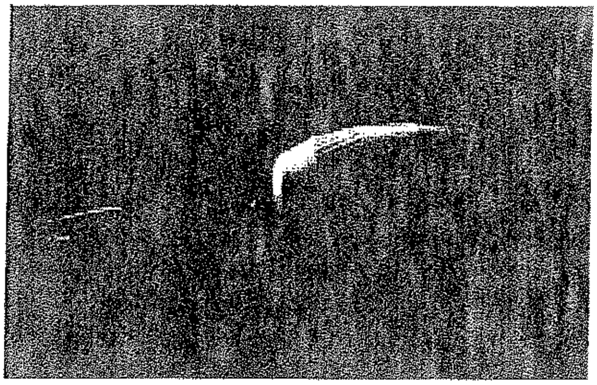
PERCEPTIONS OF NOISE INCREASES

Increase in Noise Level (dBA)	Human Perception
0 to 2	Not usually noticeable
3	Just noticeable
6	Clearly noticeable
10	Twice as loud
20	Four times as loud

Noise standards consist of two (2) types. One controls the absolute sound level that can occur. The second controls the amount of increase in sound level that a use can add to the environment. A combination of these types can also be used.

If the noise standard sets a 65 dBA threshold for a rural area, but the background noise in the rural area is currently only forty-five (45), then the ordinance would permit an increase in noise level of 20 dB, perceived as a 4-fold increase. Thus, residents in the area would perceive a very significant increase in noise. However, unless extreme protection is warranted, limiting increases, especially daytime increases, to less than 5 dB is not generally recommended.

If a relative criteria which limits the difference in sound level—the change in sound level with and without the sound source operating—is used, then a clear distinction must be made between ambient and background sound levels. While sometimes used interchangeably, they are quite different.



Reviewers must take care to ensure the proper terminology is used in reports submitted in support of applications. The standards used in this publication refer to the predevelopment ambient noise level. This is the same as the background noise level prior to the development.

The **ambient sound level** is *all* sound sources in an area and, if measured after the development occurs, includes the source in question. The **background sound level** is the level of sound from all sources except the specific source in question. Relative criteria assess the difference between the ambient (the sound level in the area with all sources) and background (the sound level in the area with all sources except the one in question) sound levels.

This difference between ambient and background noise points out the importance of definitions. Definitions must be accurate and specific if the standard is to be enforceable. Most of the definitions (at the end of the bulletin) have been taken from the rules adopted pursuant to the Maine Site Location of Development Law. They are presented to encourage consistency between local and state standards.

As with any standard, the more complex the standard, the greater the chance for misinterpretation and the more difficult enforcement becomes. Also, remember that the standards will be enforced by people with little or no background in acoustics. Therefore, a relatively simple standard which only requires the use of a simple sound level meter, rather than the use of an octave band meter (one that measures varying frequencies), is preferable. However, the standard must be specific. With today's measurement techniques and legal requirements, vague qualifications on noise such as *nuisance* or *disturbance* without any quantification will not suffice. While seemingly simple, they are vague and subjective, and virtually unenforceable.

Sound level meters and calibration equipment must comply with the latest version of ANSI standard S1.4. This standard divides sound level meters into categories called types labeled by the numbers 0, 1, or 2. Type 2 meters are the least sensitive, and type 0 are the most sensitive.

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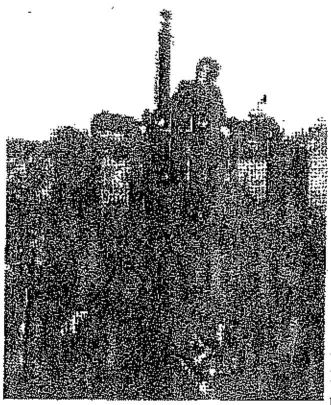
Planning Considerations

It is important to recognize the potential noise impacts on normal life events in a community. Some noise is necessary such as from emergency vehicles. Even noise from construction equipment may be necessary in order to maintain a vital community. But, much of the noise created today is capable of disturbing people as they work, play, and reside in the community. Noise is an important and often overlooked issue that requires "sound" planning.



The first part of the planning process is to consider existing and potential noise impacts in the community; this should be done in the comprehensive planning process.

The second part of managing noise in the community is to adopt clear and enforceable noise standards. The standards should be included in the standard section of site plan review, whether site review is a stand alone ordinance or part of the zoning ordinance.

Comprehensive Planning Considerations

The comprehensive plan develops the information necessary to support noise standards in ordinances. As such, it is important to provide a thorough inventory and analysis as a basis for the goals, policies, and strategies to be included in the plan. The policies and strategies form the legal basis for the land use standards adopted in local ordinances.

- The first step in the comprehensive planning process is to conduct an inventory. The plan must consider the types of uses which currently exist in the community and their location. Where are residential neighborhoods located, where are hospitals, schools, and similar institutional uses requiring quiet located, and where are outdoor recreational facilities located? Also, the town must consider where existing significant noise sources are located, the probability of new sources being developed, and the potential locations for such new sources. Existing sources in rural areas such as gravel pits, farming operations, and sawmills should not be overlooked.

- An assessment of the existing sources and potential for new sources and their locations will provide guidance in the development of the Future Land Use Plan and on whether the town may need to vary noise standards by zone.

- Once these factors are inventoried and assessed, the town must develop policies which will protect its residents, businesses, and property values but allow for new uses. The town may decide on a zoning ordinance which provides different criteria for different zones, or the town may decide on a single standard to use throughout the community. The standards in this bulletin are for town wide use as part of site review procedures.

Following are some example policies and strategies for consideration in developing a comprehensive plan.

Sample Policies

⇒ To protect the residents, businesses, institutions, and outdoor recreational areas from noise sources which would disturb living and working conditions.

⇒ To maintain the tranquil settings in residential neighborhoods (and other quiet areas).

⇒ To reduce the noise levels in the ... (a particularly noisy area of town) section of town as development patterns change.

Note: Be careful not to consider all rural areas as particularly quiet because farming, forestry, and other uses permitted in these areas produce significant noise.

Sample Strategies

⇒ The site plan review provisions should be amended to include noise standards which control noise from new development, changes in use, or expansions of use which will protect abutters, or future abutters, from noise which may disturb communications, sleep, or otherwise interfere with work and lives. The standard should be more restrictive for nighttime hours between 7:00 P.M. and 7:00 A.M.

⇒ The noise standard contained in the site plan review provisions should be amended to limit the increase in noise in the rural areas of town which are particularly quiet (identify the locations).

⇒ The noise standard in the site plan review provisions should include a requirement that uses proposed for locations which currently exceed the ambient noise level in the standard will emit a lower noise level than currently exists in the location.

Review Process

The Review Process starts with the submittal of the required information by the developer. Noise may not be an issue with many types of commercial and service related development, although in some instances, noise from traffic or delivery vehicles may be a concern to abutters. Reviewers will need to determine if noise is an issue by considering the type of development and the location. At a minimum, it may be in the municipality's best interest to obtain a statement from the developer that the noise standards will be met. The reviewing authority can then make the statement part of the application: this gives the municipality enforcement authority if, for some reason, excessive noise is generated. For proposed developments where noise is not expected to be an issue, the reviewing authority can waive further submittals. This section of the bulletin provides model ordinance language for submittal requirements; it also provides a discussion of how to apply the requirement and of how to use the information during the review process.

The next section of the bulletin provides model "standards" that the development must meet to obtain approval. The Review Standards section presents several levels of standards. A Basic Standard is presented first, followed by additional standards or more detailed standards. This Review Process section is divided into subsections which correspond to the alternative standards presented in the Review Standards section.

The left column provides a listing of documents (submittals) which municipalities should require in order to adequately review proposals. Each submittal helps the reviewing authority determine whether the standard contained in the ordinance will be met. The reviewing authority has to review and understand the submittals. The background information provided in this bulletin and the discussions of the submittals and the standards will help the authority interpret the submittals. Submittal requirements should be included in local ordinances. The town may also develop a submittal checklist so that it can easily determine if an application is complete.

The right column provides a discussion of the submittal requirements – why they are needed and how they are used in determining compliance with the standard. For Noise, the submittal requirements are the same for both the Basic and More Detailed Standards.

Submittals for All Review Standards I through III

Submittals	Discussion
A. Technical information shall be submitted describing the applicant's plan and intent to make adequate provision for the control of sound. The applicant's plan shall contain adequate information on which to determine compliance with the standard. The information shall be prepared by a qualified professional. Information should include:	A. The plans (maps) submitted for the application and the review of other standards should usually be adequate for the review of noise, except that, if noise barriers are proposed, a detailed design may be necessary. Submittals should include a locator map (USGS quadrangle map or other suitable map) with the site clearly marked and a detailed site plan as noted below.
1. A site plan with the location of noise emitters, noise controls, and any sound measurement locations clearly shown. Also, a tax map showing property parcels that may be impacted and the most recent USGS map, both having the location of the site clearly marked. (The tax map and the USGS map may be required as a basic submittal for all development.)	1. A detailed site plan showing the site, the locations of intended uses within the site, abutting property and its uses including structures and areas of intense outdoor uses, such as recreation areas that may be adversely impacted by noise, should be submitted so that the reviewer can understand the scope of the project and the properties which could be impacted. Pre- and post-development topographic maps of the site will be helpful where it is expected that topographic or physical features of the site will help to reduce noise and/or where topographic changes which may affect noise are proposed.
2. Descriptions of the existing land uses, the local zoning, and the recommended future land use in the comprehensive plan for the area potentially affected by sounds from the development.	2. The abutting uses and uses beyond the abutters possibly up to one-half mile from the site should be described and their location clearly presented. Additionally, the zoning for the area potentially impacted should be shown and described. Uses beyond abutters can be shown on the tax map or the USGS map where appropriate.

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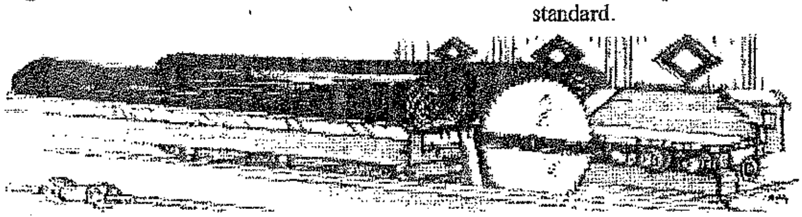
Submittals	Discussion
3. A description of major sound sources, including tonal sound sources and sources of short duration repetitive sounds, associated with the construction, operation, and maintenance of the proposed development including their locations within the proposed development.	3. The major sound sources on the site should be described including tonal and short duration noises. The sounds which will occur from both construction and operation should be noted. Any significant sounds which could result from maintenance operations should be noted. The description should reference the site plan so that the location and relationship to other sound sources can be easily understood.
4. A description of the pre-development ambient daytime and nighttime equivalent sound levels at the property boundaries of the proposed site.	4. The "pre-development ambient sound level" is the same as the pre-development background sound level. (After the development is in place, there is a difference between background and ambient noise.) The equivalent sound levels are either the one minute equivalent or the hourly equivalent depending on the standard selected. Any tonal or short duration repetitive sounds or any other unusual qualities about the existing sound in the area should be noted. Where noise is expected to be a significant issue, measurements should be taken at the property boundaries.
5. A description of the daytime and nighttime equivalent sound levels and the short duration repetitive sounds and tonal sounds expected to be produced by these sound sources at the property boundaries of the proposed development. The description shall include the maximum sound level expected for short duration repetitive sounds and tonal sounds.	5. The description of the sound levels expected maybe based on recognized literature which references the specific type of development or on measurements at a similar type of facility. For situations in which noise is a significant issue, the reviewing authority may wish to have the applicant reference several source documents and take measurements at an actual facility and possibly require a model of the sound levels based on manufacturer's specifications for the equipment generating the sound and/or any controls proposed. Noise experts sometimes use published average sound levels for varying types of neighborhoods instead of taking sound level measurements at the proposed site. They also must often use published levels for specific types of development, for example, lumber yards or junkyards, since the site is not yet developed.
6. A description of proposed major sound control measures including their locations and expected performance.	6. The description should provide references which document the expected performance of the sound control measures. Where site features such as berms are proposed, the features should be clearly shown on a post-development topographic plan of the site. The type and location of all sound control measures, including topographic and landscaping features, should be carefully documented and made part of the plan approval by notation on the plan and/or by inclusion in the Findings of Fact.
7. A comparison of the expected sound levels from the proposed development with the sound level limits of this regulation.	7. A written report comparing the expected sound levels with the pre-development ambient sound levels will help determine compliance with the standard.



Review Standards

This section presents review standards which should be included in the site plan review process of a zoning ordinance or in a stand alone site plan review ordinance. Several alternatives having varying amounts of detail are presented. The standards should be applicable to new development, expansions, and changes in use. Standards are presented in the left column, and a discussion of the standard appears in the right column.

Three (3) alternatives are presented: a basic standard, several additions to the basic standard which consider areas that may be unusually quiet and areas which currently exceed the standard, and a more detailed standard that varies with expected uses or zones.

The more detailed alternative is best used in towns with zoning so that there is no doubt about the type of future abutting land uses. It is most relevant to towns which have distinct patterns of growth and which expect considerable industrial development for which noise may be a factor. The discussion provides additional guidance on use.

Standard / **Discussion**

I. Basic Standard

This is a relatively simple sound level standard which should be easily administered. It is most suitable for small communities with few planning and code enforcement resources. It may also be suitable for many rural communities where there are few noise sensitive uses such as schools, and it is unlikely that significant noise sources would locate near them. In these communities, it is anticipated that there would be sufficient open space to buffer significant noise on the source's land so that they would not create a nuisance to abutting uses.

A. The proposed development shall not increase noise levels to the extent that abutting or nearby properties are adversely affected. In order to comply with this, the development must meet the following requirements.

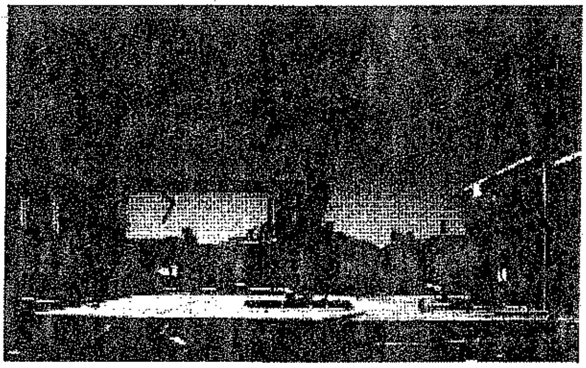
1. The maximum permissible sound level of any continuous, regular, frequent, or intermittent source of sound produced by any activity shall be limited according to the time of day and land use which abuts it as listed below.

Abutting Use	Sound Level Limits dBA	
	7 a.m. – 7 p.m.	7 p.m. – 7 a.m.
Residential	55	45
Commercial	65	55
Industrial	70	60
Institutional	55	45

2. Where the abutting property is undeveloped, the sound level shall be equal to or less than the most restrictive other abutting use. Where there are no uses on abutting properties, the sound level at the property line shall be equal to or less than the least stringent use allowed by zoning.

A. As noted in the earlier discussions, the term "Adversely affected" is vague. The standard is defined by the conditions that follow the introductory wording.

1. The hours can be changed to reflect community values and patterns. Most standards use 6 a.m. or 7 a.m. as the separation of the nighttime to daytime standard; daytime to nighttime varies from 7 p.m. to 10 p.m.



2. This is a provision to protect future uses of vacant land which abuts a noise generator. The first sentence makes the noise level at the abutting property line of vacant property less than or equal to the sound level required for the most restrictive abutting use. If a municipality is trying to transition an area to a more industrialized area, this requirement may not be appropriate. The second sentence allows the noise level for uses where there are no abutters to equal the noise level for the least

Standard | **Discussion**

restrictive possible abutting use. Thus, this type of setting could have the maximum noise level permitted by ordinance. It effectively discourages quieter uses from locating in the area.

3. Sound levels shall be measured at least four (4) feet above the ground at the property line of the development. Sound levels shall be measured by a meter set on the A-weighted response scale, fast response. The meter shall meet the latest version of American National Standards Institute (ANSI S1.4.) "American Standard Specification for General Purpose Sound Level Meters" and shall have been calibrated at a recognized laboratory within the past year.

3. This specifies the standard to be used for the sound level meter and must be included so that all measurements have a common base and accuracy.

4. The following uses and activities shall be <u>exempt</u> from the sound pressure level regulations.
   a. Noises created by construction and temporary maintenance activities between 6:30 a.m. and 8:00 p.m.
   b. The noises of safety signals, warning devices, and emergency pressure relief valves and other emergency activities.
   c. Traffic noise on public roads.
   d. Resource uses in rural areas.

4. Exemptions should be provided for some activities. The standard is based on common examples. For a list of additional exemptions, see Alternative III, Item 10.
   a. The times for construction activities can vary from those presented based upon community needs. Additionally, the exemption could be limited so that it would not apply to Sundays and/or Federal holidays. Suggested wording follows: except that noise from construction and temporary, scheduled maintenance activities shall comply with the standards on Sunday.
   d. Municipalities may want to exempt agriculture, forestry, mining in rural areas since these uses are generally allowed but often create noise above the allowable standard.

II. Possible Additions to Basic Standard

Either one or all of these additions can be included in the Basic Standard (I). (Numbering is consecutive to that standard.)

Additional standard #5 provides additional protection to areas of the community where the ambient sound level is considerably below the allowed level. It is suitable for rural communities similar to the first alternative, but which may have some very quiet areas which the town wishes to preserve.

Standard #6 provides for areas which currently have noise levels above the allowable standard. The second is suitable for communities which have a noisy area(s) which the town would like to keep from becoming worse and would like to bring more in line with the standards as existing sources cease.

Standard #7 provides for sound measurement to determine compliance in the case where no pre-development ambient sound level measurements were taken.

5. When a proposed development is to be located in an area where the daytime pre-development ambient hourly sound level (Leq 60) is equal to or less than 45 dBA and/or the nighttime pre-development ambient hourly sound level is equal to or less than 35 dBA, the hourly sound level resulting from the development shall not cause the ambient hourly

5. This standard limits the sound level emitted by new development in areas of a community that are particularly quiet. It provides for a 5 dB increase in ambient sound levels above the pre-development level. Thus, the increase will be noticeable, but it should not create a significant disturbance. It provides significant protection from noise intrusion.

Standard	Discussion
sound levels at the property lines of the development to be 5 dBA more than the ambient hourly sound level prior to development.	Towns with zoning may want to apply this standard to only some of their rural zones. Care should be used in applying this standard to areas where agriculture, forestry and/or mining are existing or expected uses.
6. If the daytime and/or nighttime pre-development ambient sound level at property line of the development site exceeds the daytime and/or nighttime limits by at least 5 dBA, then the daytime and/or nighttime limits shall be 5 dBA less than the measured daytime and/or nighttime pre-development ambient hourly sound level.	6. This provides for a development which will be located in an area where the sound level exceeds the standard set in the first section. It requires new development to emit a noise level that is lower than the existing noise level such that no further disturbance results and so that as noisier developments cease to operate, the area will have an ambient sound more closely in compliance with the rules.
7. In the absence of a measurement of "pre-development ambient" sound level, enforcement may be based on the post-development background level.	7. This standard accounts for cases where there is no pre-development sound level measurement. The pre-development level is approximated by the "background" level after development.

III. More Detailed Standard – Suitable for Use with a Zoning Ordinance

This is an alternative standard which is somewhat more complex. It parallels DEP's existing Site Location of Development rules but has been simplified. The sound levels and the times may be changed to reflect community needs. It accounts for future land use by referencing zoning and is probably best used as part of a Site Plan Review (or Conditional Use) procedure within a Zoning Ordinance. It is most suitable, with the levels used here, for a more developed community than the first alternative. Note that sound levels are generally 5 dB higher. It may be modified for use with a Site Plan Review Ordinance or for a more rural community.

A. The hourly sound levels at the property line of the development and resulting from the development shall not exceed the following limits:

Standard	Discussion
1. Any location for which the zoning is <u>not</u> predominantly commercial or industrial: 60 dBA between 7:00 a.m. and 7:00 p.m. 50 dBA between 7:00 p.m. and 7:00 a.m.	1. This sets the standard where abutting uses are residential, institutional, or open space. The Zoning Ordinance would designate the abutting area as one of these types of uses.
2. At any location for which the zoning is predominantly commercial or industrial: 70 dBA between 7:00 a.m. and 7:00 p.m. 60 dBA between 7:00 p.m. and 7:00 a.m.	2. This sets the standard where abutting uses are businesses or industrial use. It allows a source to emit more noise than the source could emit in a residential or institutional area. The noise allowed in this location would be perceived as being twice as loud for the location with a residential buffer.
3. When a proposed development is to be located in an area where the daytime pre-development ambient hourly sound level is equal to or less than 45 dBA and/or the nighttime pre-development ambient hourly sound level is equal to or less than 35 dBA, the hourly sound levels resulting from the development shall not exceed the following limits when the zoning of the abutting use is <u>not</u> predominantly commercial or industrial. 55 dBA between 7:00 a.m. and 7:00 p.m. 45 dBA between 7:00 p.m. and 7:00 a.m.	3. This standard provides for a lower sound level for locations where abutters would be residential or institutional when the existing sound level is quite low. It allows for a doubling of the perceived increase.

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Standard	Discussion
4. If the daytime and/or nighttime pre-development ambient sound environment exceeds the daytime and/or nighttime limits in subsection 2(a) or 2(b) by at least 5 dBA, then the daytime and/or nighttime limits shall be 5 dBA less than the measured daytime and/or nighttime pre-development ambient hourly sound level at the location of the measurement for the corresponding time period.	4. This provides for a development which will be located in an area where the sound level exceeds the standard set in the first section. It requires new development to emit a noise level that is lower than the existing noise level such that no further disturbance results and so that as noisier developments cease to operate, the area will have an ambient sound more closely in compliance with the rules.
5. When development produces tonal sounds or short duration repetitive sounds: Five (5) dBA shall be added to the observed levels of these sounds for the purposes of determining compliance with the sound level limits herein established.	5. This standard accounts for the fact that tonal and repetitive sounds are more annoying than multi-band, constant noises. To account for this, 5 dB is added to the tonal or repetitive sound level measured (or expected). Thus tonal or repetitive sounds would not be as loud as other noises.
6. The maximum sound level of the short duration repetitive sounds shall not exceed the following limits: a. At any location for which the zoning is <u>not</u> predominantly commercial, transportation, or industrial: 65 dBA between 7:00 a.m. and 7:00 p.m. and 55 dBA between 7:00 p.m. and 7:00 a.m. b. At any location for which the zoning is predominantly commercial, transportation, or industrial: 75 dBA between 7:00 a.m. and 7:00 p.m., and 65 dBA between 7:00 p.m. and 7:00 a.m.	6. This standard controls the maximum sound level from short duration, repetitive sources.
7. Sound from construction activities between 6:30 a.m. and 8:00 p.m. shall not exceed the limits established in the table on page 11 at the property line. Between 8:00 p.m. and 6:30 a.m., sound levels shall comply with the other standards presented herein.	7. This standard provides actual limits to noises produced during construction, and it requires all equipment to comply with federal standards and original equipment design.
8. All equipment used in construction on development sites shall comply with applicable federal noise regulations and shall include environmental noise control devices in proper working condition as originally provided with the equipment by its manufacturer.	8. This specifies the standard to be used for the sound level meter and must be included so that all measurements have a common base and accuracy.
9. Noise shall be measured by a meter set on the A-weighted response scale, fast response. The meter shall meet the latest version of American National Standards Institute (ANSI S1.4.) "American Standard Specification for General Purpose Sound Level Meters."	
10. In the absence of a measurement of "pre-development ambient" sound level, enforcement may be based on the post-development background level.	10. This standard accounts for cases where there is no pre-development sound level measurement. The pre-development level is approximated by the

Standard | Discussion

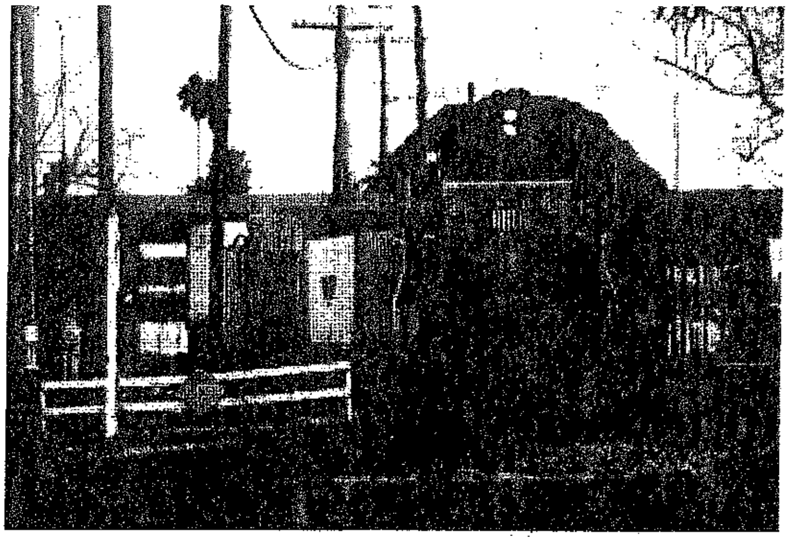
"background" level after development. The post-development background noise is the noise after the development is constructed but with no noise being produced by the development.

11. Sound associated with the following shall be exempt from regulation by the Board:

Construction Activity Sound Limits (7:00 a.m. to 7:00 p.m.)	
Duration of Activity	**Hourly Sound Level Limit**
12 hours	87 dBA
8 hours	90 dBA
6 hours	92 dBA
4 hours	95 dBA
3 hours	97 dBA
2 hours	100 dBA
1 hour or less	105 dBA

- The noises of safety signals, warning devices and emergency pressure relief valves and other emergency activities.
- Traffic noise on public roads.
- Railroad equipment which is subject to federal noise regulations.
- Aircraft operations at public airports or which are subject to federal noise regulations.
- Bells, chimes, and carillons.
- Occasional sporting, cultural, religious, or public events.
- Farming and forest management, harvesting, and transportation activities.

11. This list is similar to the list from the DEP Site Location Law rules. It is more specific than the exceptions provided for the other Alternatives.



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Definitions

Ambient Sound: At a specified time, the all-encompassing sound associated with a given environment, being usually a composite of sounds from many sources at many directions, near and far, including the specific development of interest.

Background Sound: The all-encompassing sound associated with a given environment, being a composite of sounds from many sources at many directions, near and far, prior to the construction of the proposed development. Also referred to as the **pre-development ambient** sound.

Equivalent Sound Level: The level of the mean-square A-weighted sound pressure during a stated time period, or equivalently the level of the sound exposure during a stated time period divided by the duration of the period.

Hourly Sound Level: The equivalent sound level for a one- (1) hour period.

Maximum Sound: Largest A-weighted and fast exponential-time-weighted sound during a specified time interval. Unit of measure is the pascal (Pa).

Pre-Development Ambient: The ambient sound at a specified location in the vicinity of a development site prior to the construction and operation of the proposed development or expansion.

Short Duration Repetitive Sounds: A sequence of repetitive sounds which occur more than once within an hour, each clearly discernible as an event and causing an increase in the sound level of at least 6 dBA on the fast meter response above the sound level observed immediately before and after the event, each typically less than ten (10) seconds in duration, and which are inherent to the process or operation of the development and are foreseeable. They include sounds which repeat on a regular basis and sounds which have a scattered time of occurrence.

Sound Level: Ten (10) times the common logarithm of the square of the ratio of the frequency-weighted and time-exponentially averaged sound pressure to the reference sound of 20 micropascals. For the purpose of this regulation, sound level measurements are obtained using the A-weighted frequency response and fast dynamic response of the measuring system, unless otherwise noted.

Sound Pressure: Root-mean-square of the instantaneous sound pressure in a stated frequency band and during a specified time interval. Unit of measure is the pascal (Pa).

Sound Pressure Level: Ten (10) times the common logarithm of the square of the ratio of the sound pressure to the reference sound pressure of 20 micropascals.

Tonal Sound: For the purpose of this regulation, a tonal sound exists if the one-third (1/3) octave band sound pressure level in the band containing the tonal sound exceeds the arithmetic average of the sound pressure levels of the two (2) contiguous one-third (1/3) octave bands by 5 dB for center frequencies at or between 500 Hz and 10,000 Hz, by 8 dB for center frequencies at or between 160 and 400 Hz, and by 15 dB for center frequencies at or between 25 Hz and 125 Hz.

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THE "HOW TO" GUIDE TO SITING WIND TURBINES TO PREVENT HEALTH RISKS FROM SOUND

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"A subset of society should not be forced to bear the cost of a benefit for the larger society."[1]

I. Introduction

A new source of community noise is spreading rapidly across the rural U.S. countryside. Industrial-scale wind turbines (WT), a common sight in many European countries, are now actively promoted by federal and state governments in the U.S. as a way to reduce coal-powered electrical generation and global warming. The presence of industrial wind projects is expected to increase dramatically over the next few years, given the tax incentives and other economic and political support currently available for renewable energy projects in the U.S.

As a part of the widespread enthusiasm for renewable energy, state and local governments are promoting "Model Ordinances" for siting industrial wind farms which establish limits for noise and other potential hazards. These are used to determine where wind projects can be located in communities, which are predominantly rural and often extremely quiet during the evening and night. Yet, complaints about noise from residents near existing industrial wind turbine installations are common. This raises serious questions about whether current state and local government siting guidelines for noise are sufficiently protective for people living close to the wind turbine developments. Research is emerging that suggests significant health effects are associated with living too close to modern industrial wind turbines. Research into the computer modeling and other methods used to determine the layout of wind turbine developments, including the distance from nearby residences, is at the same time showing that the output of the models may not accurately predict sound propagation. The models are used to make decisions about how close a turbine can be to a home or other sensitive property. The errors in the predicted sound levels can easily result in inadequate setback distances thus exposing the property owner to noise pollution and potential health risks. Current information suggests the models should not be used for siting decisions unless known errors and tolerances are applied to the results.

Our formal presentation and paper on this topic (*Simple guidelines for siting wind turbines to prevent health risks*) is an abbreviated version of this essay. The formal paper was presented to the Institute of Noise Control Engineers (INCE) at its July Noise-Con 2008 conference in Detroit, MI, A copy of

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1 George S. Hawkins, Esq., *"One Page Takings Summary: U.S Constitution and Local Land Use,"* Stony Brook-Millstone Watershed Association; *"...nor shall private property be taken for public use, without just compensation."* Fifth Amendment, US Constitution.

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the paper is included at the end of this document. The formal paper covered the community noise studies performed in response to complaints, research on health issues related to wind turbine noise, critiques of noise studies performed by consultants working for the wind developer, and research/technical papers on wind turbine sound immissions and related topics. The formal paper also reviewed sound studies conducted by consultants for governments, the wind turbine owner, or the local residents for a number of sites with known health or annoyance problems. The purpose was to determine if a set of simple guidelines using dBA and dBC sound levels can serve as the 'safe' siting guidelines for noise and its effects on communities and people. The papers considered in our review included, but were not limited to, those listed in Tables 1-4 on pages 2 through 4 of the Noise-Con document.

This essay expands upon the Noise-Con paper and includes information to support the findings and recommended criteria. We are proposing very specific, yet reasonably simple to implement and assess criteria for audible and non-audible sound on adjacent properties and also present a sample noise ordinance and the procedures needed for pre-construction sound test, computer model requirements and follow-up tests (including those for assessing compliance).

The purpose of this expanded paper is to outline a rational, evidence-based set of criteria for industrial wind turbine siting in rural communities, using:

1) A review of the European and other wind turbine siting criteria and existing studies of the prevalence of noise problems after construction;
2) Primary review of sound studies done in a variety of locations in response to wind turbine noise complaints (Table 1);
3) Review of publications on health issues for those living in close proximity to wind turbines (Table 2);
4) Review of critiques of pre-construction developer noise impact statements (Table 3); and
5) Review of technical papers on noise propagation and qualities from wind turbines (Table 4).

The Tables are on pages 2-4 of the formal paper. We also cite standard international criteria for community noise levels and allowances for low-frequency noise.

The specific sections are:

1. Introduction (This section)
2. Results of Literature Review and Sound Studies
3. Development of Siting Criteria
4. Proposed Sound Limits
5. How to Include the Recommended Criteria in Local or State Noise Ordinances
6. Elements of a Wind Energy System Licensing Ordinance
7. Measurement Procedures (Appendix to Ordinance)
8. The Noise-Con 2008 paper "Simple guidelines for siting wind turbines to prevent health risks" with revisions not in the paper included in the conference's Proceedings.

The construction of large WT (industrial wind turbines) projects in the U.S. is a relatively recent phenomenon, with most projects built after 2000. Other countries, especially in Europe, have been using wind energy systems (WES) since the early 1990's or earlier. These earlier installations generally used turbines of less than 1 MW capacity with hub heights under 61 m (200 feet). Now, many of these earlier turbines reaching the end of their useful life, are being replaced with the

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larger 1.5 to 3 MW units. Thus, the concepts and recommendations in this article, developed for the 1.5 MW and larger turbines being build in the U.S, may also be applicable abroad.

II. Results of Literature Review and Sound Studies

In the U.K. there are currently about 133 operating WT developments. Many of these have been in operation for over 10 years. The Acoustic Ecology Institute[2] (AEI) reported that a Special Report for the British government titled "Wind Energy Noise Impacts,"[3] found that about 20% of the wind farms in the U.K. generated most of the noise complaints. Another study commissioned by British government, from the consulting firm Hayes, McKensie, reported that only five of 126 wind farms in the U.K. reported problems with the noise phenomenon known as aerodynamic modulation.[4] Thus, experience in the U. K. shows that not all WT projects lead to community complaints. AEI posed an important question: **"What are the factors in *those* wind farms that may be problematic, and how can we avoid replicating these situations elsewhere?"**

As experienced industrial noise consultants ourselves, we would have expected the wind industry, given the U.K. experience, to have attempted to answer this question, conducting extensive research – using credible independent research institutions – before embarking on wind power development in the U.S. The wind industry was aware, or should have been aware, that 20% of British wind energy projects provoked complaints about noise and/or vibration, even in a country with more stringent noise limits than in the U.S.

The wind industry complies with stricter noise limits in the U.K. and other countries than it does in the U.S., for example[5]:

- Australia: higher of 35 dBA or L_{90} + 5 dBA
- Denmark: 40 dBA
- France: L_{90} + 3 dBA (night) and L_{90} + 5 dBA (day)
- Germany: 40 dBA
- Holland: 40 dBA
- United Kingdom: 40 dBA (day) and 43 dBA or L_{90} + 5 dBA (night)
- Illinois: Octave frequency band limits of about 50 dBA (day) and about 46 dBA (night)
- Wisconsin: 50 dBA
- Michigan: 55 dBA

Industry representatives on state governmental committees have worked to establish sound limits and setbacks that are lenient and favor the industry. In Michigan, for example, the State Task Force (working under the Department of Labor and Economic Growth) recommended in its "Siting Guidelines for Wind Energy Systems" that the limits be set at 55 dBA or L_{90} + 5 dBA, whichever is higher. In Wisconsin, the State Task Force has recommended 50 dBA.

When Wisconsin's Town of Union wind turbine committee made an open records request to find out the scientific basis for the sound levels and setbacks in the state's draft model ordinance, it found that no scientific or medical data was used at all. Review of the meeting minutes provided

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2 (http://www.acousticecology.org/srwind.html)

3 AEI is a 501(c)3 non-profit organization based in Santa Fe, New Mexico, USA. The article is available at http://www.acousticecology.org/srwind.html

4 Study review available at: http://www.berr.gov.uk/files/file35592.pdf

5 Ramakrishnan, Ph. D., P. Eng., Ramani, "Wind Turbine Facilities Noise Issues" Dec. 2007 Prepared for the Ontario Ministry of Environment.

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under the request showed that the limits had been set by Task Force members representing the wind industry.[6] This may explain why state level committees or task forces have drafted ordinances with upper limits of 50 dBA or higher instead of the much lower limits applied to similar projects in other countries. There is no independent, scientific or medical support for claims that locating 400+ foot tall wind turbines as close as 1000 feet (or less) to non-participating properties will not create noise disturbances, economic losses or other risks.[7] But, there is considerable independent research supporting that this will result in public health risks and other negative impacts on people and property.

To illustrate the way a typical WT developer responds to a question raised by a community committee about noise and health the following example is presented and discussed:

> **Q: 19. What sound standards will EcoEnergy ensure that the turbines will be within, based on the setbacks EcoEnergy plans to implement, and what scientific and peer reviewed data do you have to ensure and support there will be no health and safety issues to persons within your setbacks?**
>
> **Answer:** As mentioned, turbines are sited to have maximum sound level of 45dBA. These sound levels are well below levels causing physical harm. Medical books on sound indicate sound levels above 80-90dBA cause physical (health) effects. The possible effects to a person's health due to "annoyance" are impossible to study in a scientific way, as these are often mostly psychosomatic, and are not caused by wind turbines as much as the individuals' obsession with a new item in their environment.
>
> **From EcoEnergy's "Response to the Town of Union Health & Safety Research Questionnaire"**
> By Curt Bjurlin, M.S., Wes Slaymaker, P.E., Rick Gungel, P.E., EcoEnergy, L.L.C., submitted to Town of Union, Wisconsin and Mr. Kendall Schneider, on behalf of the Town of Union

A serious question was asked and it deserves a responsible answer. The committee, charged with fact-finding, sought answers they presumed would be based on independent, peer-reviewed studies. Instead, the industry response was spurious and misleading, and did not address the question. It stated that the turbines will be located so as to produce maximum sound levels of 45 dBA, the tone and context implying that 45 dBA is fully compatible with the quiet rural community setting. No acknowledgement is made of the dramatic change this will be for the noise environment of nearby families. No mention is made of how the WT, once in operation, will raise evening and nighttime background sound levels from the existing background levels of 20 to 30 dBA to 45 dBA. There is no disclosure of the considerable low frequency content of the WT sound; in fact, there are often claims to the contrary. They fail to warn that the home construction techniques used for modern wood frame homes result in walls and roofs that cannot block out WT low frequencies.

There is no mention of the nighttime sound level recommendations set by the World Health Organization (WHO) in its reports, *Guidelines for Community Noise* [8] and "Report on the third

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6 Lawton, Catharine M., Letter to Wisconsin's "Guidelines and Model Ordinances Ad Hoc Subcommittee of the Wisconsin Wind Power Siting Collaborative" in Response to Paul Helgeson's 9/20/00 "Wisconsin Wind Ordinance Egroups E-Mail Message," Sept. 20, 2000, a Public Record obtained through Open Meetings Act request by the Town of Union, Wisconsin, Large Wind Turbine Citizens Committee.

7 It is worth noting that the 2007-06-29 version of the Vestas Mechanical Operating and Maintenance Manual for the model V90 – 3.0 MW VCRS 60 Hz turbine includes this warning for technicians and operators:

> **"2. Stay and Traffic by the Turbine**
>
> Do not stay within a radius of 400m (1300ft) from the turbine unless it is necessary. If you have to inspect an operating turbine from the ground, do not stay under the rotor plane but observe the rotor from the front.
> Make sure that children do not stay by or play nearby the turbine. ...."

8 Available at http://www.who.int/docstore/peh/noise/guidelines2.html.

meeting on night noise guidelines.[9]" In these documents WHO recommends that sound levels **during nighttime and late evening hours should be less than 30 dBA during sleeping periods to protect children's health.** They noted that a child's autonomic nervous system is 10 to 15 dB more sensitive to noise than is an adult. Even for adults, health effects are first noted in some studies when the sound levels exceed 32 dBA L_{max}. These sounds are 10-20 dBA lower than the sound levels needed to cause awakening.

For sounds that contain a strong low frequency component, which is typical of wind turbines, WHO says that the limits may need to be even lower than 30 dBA to avoid health risks. Further, they recommend that the criteria use dBC frequency weighting instead of dBA for sources with low frequency content. When WT sound levels are 45 dBA outside a home, we may find that the interior sound levels will drop to the 30 dBA level recommended for sleeping areas but low frequency noise only decreased 6-7 dBC from outside to inside. That could create a sleep problem because the low frequency content of the noise can penetrate the home's walls and roof with little reduction. An example demonstrating how WT sound is affected by walls and windows is provided later in this document.

The wind turbine developers in the excerpt above do not disclose that the International Standards Organization (ISO) in ISO 1996-1971 recommends 25 dBA as the maximum night-time limit for rural communities. As can be seen in the table below, sound levels of 40 dBA and above are only appropriate in suburban communities during the day and urban communities during day and night. There are no communities where 45 dBA is considered acceptable at night.

ISO 1996-1971 Recommendations for Community Noise Limits (dBA)			
District Type	Daytime Limit	Evening Limit 7-11pm	Night Limit 11pm-7am
Rural	35dB	**30dB**	**25dB**
Suburban	40dB	35dB	**30dB**
Urban residential	45dB	40dB	35dB
Urban mixed	50dB	45db	40dB

Further, the wind industry claims, "*These sound levels are well below levels causing physical harm. Medical books on sound indicate sound levels above 80-90dBA cause physical (health) effects.*" Concern about sound levels in the 80-90 dBA range is for hearing health (your ears) and not the health-related issues of sleep disturbance and other symptoms associated with prolonged exposure to low levels of noise with low frequency and amplitude modulation such as the sound emitted by modern wind turbines. This type of response is a non-answer. It is an overt attempt to mislead while giving the appearance of providing a legitimate response.

Furthermore, the statement, "*The possible effects to a person's health due to 'annoyance' are impossible to study in a scientific way, as these are often mostly psychosomatic, and are not caused by wind turbines as much as the individuals' obsession with a new item in their environment,*" is both inaccurate and misleading. It ignores the work of researchers such as Pedersen, Harry, Phipps, and Pierpont on wind turbine effects specifically, and the numerous medical research studies reviewed by Frey and Hadden. The studies belie the claims of the wind industry. This "failure to locate" published

[9] Available at: http://www.euro.who.int/Noise/activities/20040721_1 References found in Report on third meeting at pages 13 and others

studies that are readily available on the internet as to make some interpret the claim of "no medical research" as a conscious decision to not look for it. Those companies that do acknowledge the existence of medical research take the position that it is not credible for one or another reason and thus can be ignored.

Making statements outside their area of competence, wind industry advocates, without medical qualifications, label complaints of health effects as "psychosomatic" in a pejorative manner that implies the complaints can be discounted because they are not "really medical" conditions. Such a response cannot be considered to be based in fact. It is, at best, an opinion. It ignores the work of many researchers, including the World Health Organizations, on the effect of sounds during nighttime hours that result in sleep disturbance and other disorders with physical, not just psychological, pathologies.[10,11] Many people find it difficult to articulate what has changed. They know something is different from before the wind turbines were operating and they may express it as feeling uncomfortable, uneasy, sleepless, or some other symptom, without being able to explain why it is happening.

Our review of the studies listed in Tables 1-4 of our Noise-Con paper show that some residents living as far as 3 km (1.86 mi) from a wind farm complain of sleep disturbance from the noise. Many residents living 1/10 of this distance (300 m or 984 ft) from wind farms experience major sleep disruption and other serious medical problems from nighttime wind turbine noise. The peculiar acoustic characteristics of wind turbine noise immissions[12] cause the sounds at the receiving properties to be more annoying and troublesome than the more familiar noise from traffic and industrial factories. Limits used for these other community noise sources are not appropriate for siting modern industrial wind turbines. The residents who are annoyed by wind turbine noise complain of the repetitive, approximately once-per-second (1 Hz) "swoosh-boom-swoosh-boom" sound of the turbine blades and of "low frequency" noise. It is not clear to us whether the complaints about "low frequency" noise are about the audible low frequency part of the "swoosh-boom" sound, the once-per-second amplitude modulation (amplitude modulation means that the sound varies in loudness and other characteristics in a rhythmic pattern) of the "swoosh-boom" sound, or some combination of the two.

Figure 1 of our Noise Con paper, reproduced as Figure 1, below, shows the data from one of the complaint sites plotted against the sound immission spectra for a modern 2.5 MWatt wind turbine; A home in the United States at 2km distance, Young's threshold of perception for the 10% most sensitive population (ISO 0266); and a spectrum obtained for a rural community during a three hour, 20 minute test from 11:45 pm until 3:05 am on a windless June evening near Ubly, Michigan. This is a quiet rural community located in central Huron County (also called Michigan's Thumb). It is worth noting that this sound measurement sample demonstrates how quiet a rural community can be when located at a distance from industry, highways, and airport related noise emitters.

The line representing the threshold of perception is the focus of this graph. The remaining graphs show sound pressure levels (dB) at each of the frequency ranges from the lowest inaudible sounds at the left, to sounds that "rumble" (20Hz to about 200 Hz) and then those in the range of communication (200Hz through about 4000Hz) through high pitched sounds (up to 10,000 Hz). At

10 WHO European Centre for Environment and Health, Bonn Office, "Report on the third meeting on night noise guidelines," April 2005.

11 According to Online Etymology Dictionary, *psychosomatic* means "pertaining to the relation between mind and body, ... applied from 1938 to physical disorders with psychological causes."

12 *Emissions* refer to acoustic energy from the viewpoint of the sound emitter, while *immissions* refer to acoustic energy from the viewpoint of the receiver.

each frequency where the graphs of sound pressures are above (exceed) the graph showing perception the wind turbine sounds would be perceptible or audible. The more the wind turbine sound exceeds the perception curve the more pronounced it will be. When it exceeds the quiet rural background sound level (L_{A90}) it will not be masked or obscured by the rural soundscape.

The over-all sounds from each of the frequency bands are summed and presented on the right hand side of the graph. These are presented with corrections for A-weighting (dBA) and C-weighting (dBC). These show that if only dBA criteria are used to assess and limit wind turbine sound the low frequency content of the wind turbines emissions are not revealed. Note that in many cases the values for dBC are almost 20 dB higher than the dBA values. This is the basis for the WHO warning that when low frequency sound content is present outside a home dBA is not an appropriate method of describing predicted noise impacts, sound limits, or criteria.

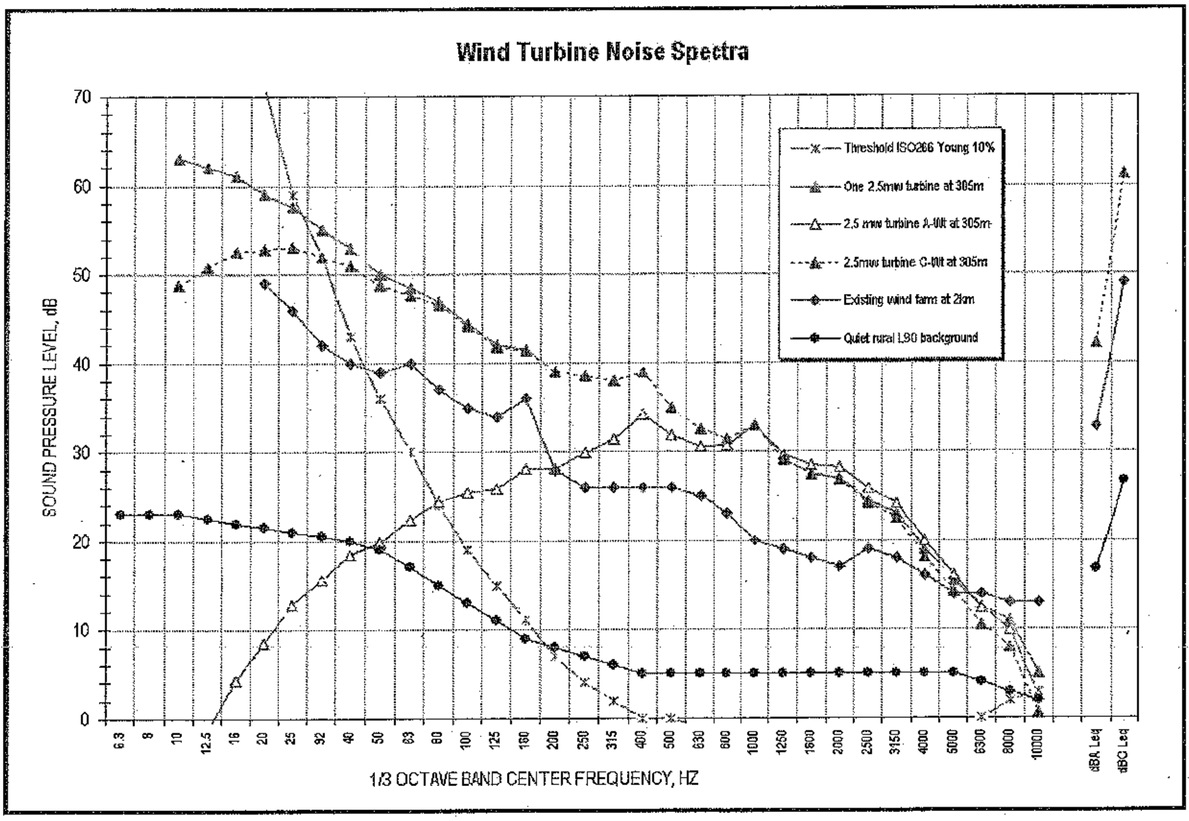

Figure 1-Graph Of Wind Turbine Sounds Vs. Rural Background And Threshold Of Perception

(Note: The lowest L_{Aeq} and L_{Ceq} shown at right are measured background L_{A90} and L_{C90}. The Leq values could be 0-5 dB higher)

Our review of the studies listed in Tables 1-4 in the Noise-Con paper at the end of this document, provided answers to a number of significant questions we had, as acoustical engineers, regarding the development of siting guidelines for industrial-scale wind turbines. They are provided below for easy of reading and continuity:

Do international, national, or local community noise standards for siting wind turbines near dwellings address the low frequency portion of the wind turbines' sound immissions? No. State and local governments are in the process of establishing wind farm noise limits and/or wind turbine setbacks from nearby residents, but the standards incorrectly assume that limits based on dBA levels are sufficient to protect the residents.

Do wind farm developers have noise limit criteria and/or wind turbine setback criteria that apply to nearby dwellings? Yes. But the industry-recommended wind turbine noise levels (typically 50-55 dBA) are too high for the quiet nature of the rural communities and may be unsafe for the nearest residents. An additional concern is that some of the methods for pre-construction computer modeling may predict sound levels that are too low. These two factors combined can lead to post-construction complaints and health risks.

An example of a condition that complies with

Are all residents living near wind farms equally likely to be affected by wind turbine noise? No. Children, people with certain pre-existing medical conditions, and the elderly are likely to be the most susceptible. Some people are unaffected while nearby neighbors develop serious health problems caused by exposure to the same wind turbine noise.

How does wind turbine noise impact nearby residents? Wind turbine-associated symptoms include sleep disturbance, headache, ringing in the ears, dizziness, nausea, irritability, and problems with memory, concentration, and problem solving, as described in the first paper in this volume.

What are the technical options for reducing wind turbine noise immission at residences? There are only two options: 1) increase the distance between the source and receiver, or 2) reduce the source sound power emission. Either solution is incompatible with the objective of the wind farm developer, which is to maximize the wind power electrical generation within the land available.

Is wind turbine noise at a residence much more annoying than traffic noise? Yes. Researchers have found that, "Wind turbine noise was ... found to cause annoyance at sound pressure levels lower than those known to be annoying for other community noise sources, such as road traffic. ...Living in a clearly rural area in comparison with a suburban area increases the risk of annoyance with wind turbine noise.[13]" In other papers by Pedersen wind turbine noise was perceived by about 85% of respondents to the study at sound levels as low as 35.0–37.5 dBA.[14] Currently, this increased sensitivity is believed to be due to the presence of amplitude modulation in the wind turbine's sound emissions which limits the masking effect of other ambient sounds and the low frequency content which is associated with the sounds inside homes and other buildings.

Amplitude modulation is a continuing change in the sound level in synchronization with the turning of the wind turbine's blades. An example of amplitude modulation is shown in the figure 2 below. This figure shows the constantly varying dBA sound level in the graph at the top. The sound level varies from a low of 40 dBA to a high of 45 dBA repeating every 1.3 seconds continuously when the turbine is operating. The turbine is located approximately 1200 feet from the farmhouse. The photo shows the turbine that was dominant during this test.

[13] Pedersen E, Bouma J, Bakker R and Van den Berg F, "Wind Farm perception- A study on acoustic and visual impact of wind turbines on residents in the Netherlands;" 2nd International Meeting on Wind Turbine Noise, Lyon France; Sept. 20-21, 2007 (Pages 2 and 3)

[14] Pedersen E and Persson Waye K. 2004. Perceptions and annoyance due to wind turbine noise -- a dose-response relationship. J Acoust Soc Am 116(6): 3460-3470

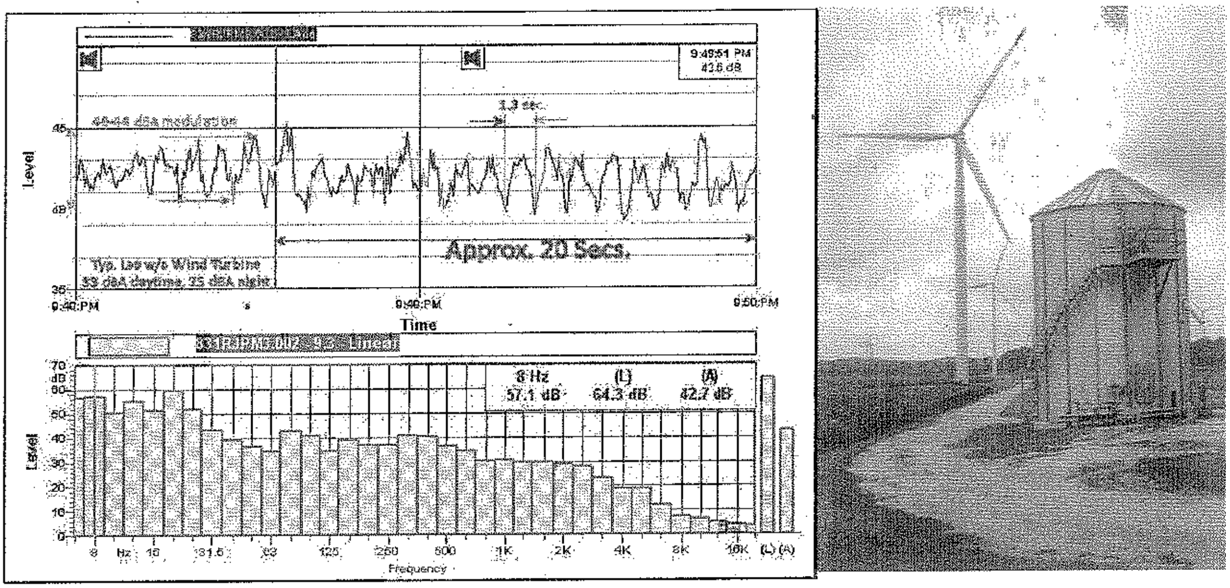

Figure 2 Amplitude Modulation at a farmhouse (Study sponsored by CCCRE, Calumet, Wisconsin)

It is worth noting that this measurement averages about 43 dBA (L_{eq}) which is very close to the sound level predicted for a single turbine at 1000 feet in Figure 1 (solid red line with solid triangle markers). The lower graph shows the frequency spectrum at approximately 9:49 PM at a low point in the amplitude modulation. (The frequency chart's cursor is the vertical line at the upper graph's midpoint.) Note the dominance of sound energy in the lower frequency range. This was also present in the model's predictions in Figure 1.

It is not hard to understand why many people in this community feel that they have been forced to accept noise pollution as a side effect of the wind project. Even though the 40 to 45 dBA sound levels in this example may comply with the 50 dBA limits adopted by the host county from the Wisconsin Model Ordinance the impact on the people near the wind project are subjected to noise pollution. This example demonstrates why criteria set at 50 dBA or higher do not protect the health and economic welfare of people living in the host communities. Adopting criteria such as those recommended later in this essay can prevent these situations from occurring.

Low frequency noise is a problem inside buildings

When low frequency sound is present outside homes and other occupied structures, it is often more an indoor problem than an outdoor one. This is very true for wind turbine sounds.

Why do wind turbine noise immissions of only 35 dBA disturb sleep at night? Affected residents complain of the middle- to high-frequency, repetitive swooshing sounds of the rotating turbine blades at a constant rate of about 1 Hz, plus low frequency noise. The amplitude modulation of the "swooshing" sound changes continuously. Residents also describe a thump or low frequency banging sound that varies in amplitude up to 10 dBA in the short interval between the swooshing sounds. This may be a result of sounds from multiple wind turbines with similar spectral content combining to increase and decrease the sound over and above the effects of modulation. [Note: These effects (e.g. phasing and coherence effects) are not normally considered in predictive models.] It may also be a result of turbulence of the air and wind on wind turbine operations when the blades are not at an optimum angle for noise emissions and/or power generation. It is also a result of sounds penetrating homes and other buildings at night and at other times where quiet is needed. When low frequency sound is present outside homes and other occupied structures, it is

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often more likely to be an indoor problem than an outdoor one. This is very true for wind turbine sounds.

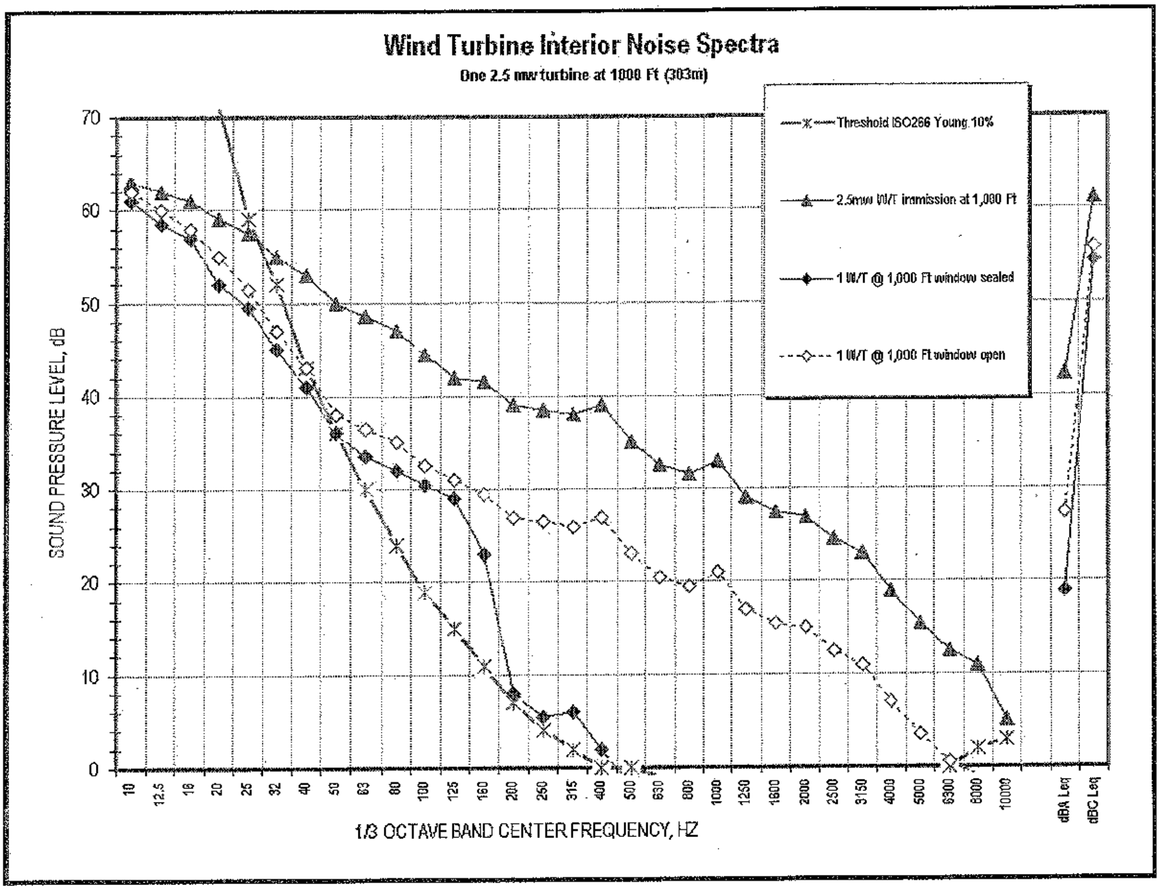

Figure 3-A Single Wind Turbine Sound Inside Home @ 1000 Feet

The usual assumption about wall and window attenuation being 15 dBA or more, which is valid for most sources of community noise, may not be sufficiently protective given the relatively high amplitude of the wind turbines' low frequency immission spectra. Figures 2 and 3 demonstrate the basis for this concern.

To demonstrate the effects of outdoor low frequency content from wind turbines we prepared Figure 1 showing the effect of a single turbine (propagation model based on sound power level test data) at 1000 feet and then in Figure 4 projected the impact of ten (10) similar turbines at one (1) mile. We applied the façade sound isolation data from the Canada Research Council to the wind turbine example used in our Noise-Con 2008 paper and shown in Figure 1 above. The graphs each show the outdoor sound pressure levels predicted for the distance of 1000 feet and one mile as the upper graph line respectively. The curve showing the threshold of human perception for sounds at each 1/3 octave band center is also plotted. When the graphs representing wind turbine sound have data points above this threshold curve the sounds will be perceptible to at least 10% of the population (which includes most children).

In addition to the top graph line representing the sounds outside the home there are two other graph lines for the sounds inside the home[15]. One curve represents the condition of no open windows and the other represents one open window.

With just one turbine at 1,000 feet there is a significant amount of low frequency noise above hearing threshold within rooms having exterior walls without windows or very well sealed windows. Even with the windows closed the sound pressure levels in the 63 Hz to 200 Hz one-octave bands still exceed the perception curve, in many cases by more than 10 dB. Note the perceptible sound between 50 and 200 Hz with a wall resonance frequency at 125 Hz (2 X 4 studs on 16 inch centers) for the "windows closed" condition. This would be perceived as a constant low rumble, which would be present inside homes whenever the turbines are operating.

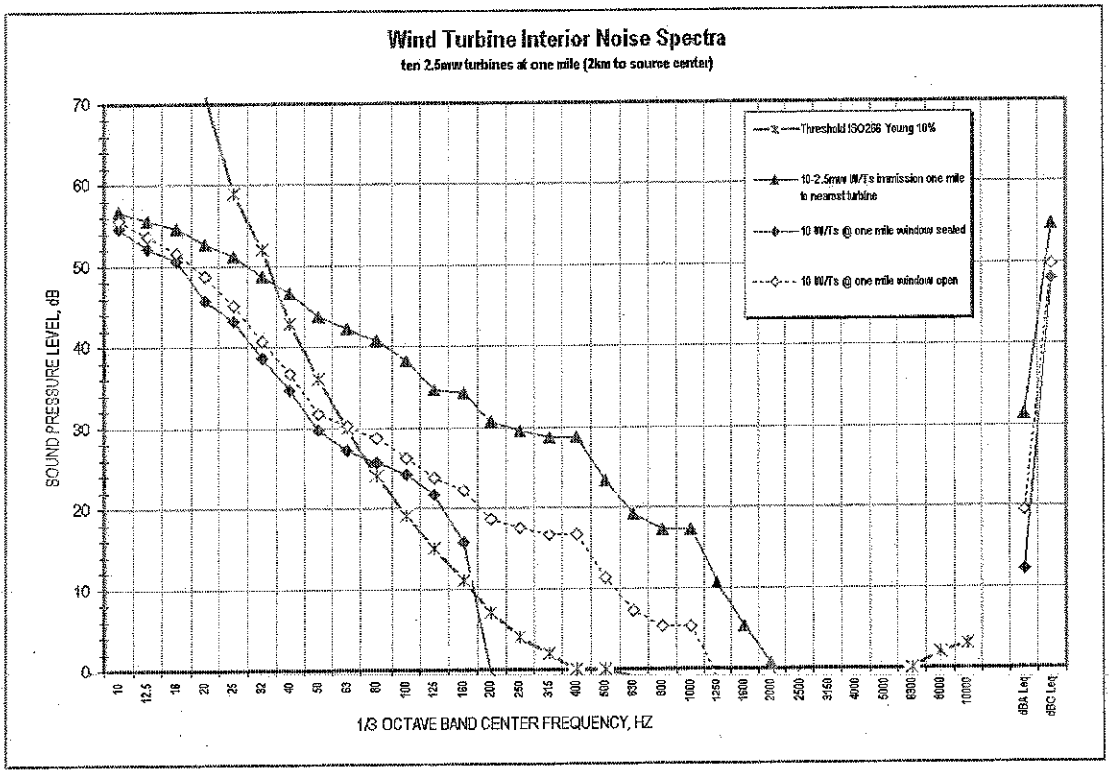

Figure 4-Sound from Ten (10) Wind Turbines inside home at One Mile

When comparing the dBC values the difference between inside sounds and outside is much less. The maximum difference in this example is only 7 dBC and that is for the situation with windows closed. With windows open the sound inside the home would be 56 dBC while it is 61 dBC outside; a difference of only 5 dBC[16,17,18]. If we looked only at dBA it would appear that the home's

[15] The typical wood stud exterior used in modern home construction is vinyl siding over 1/2 inch OSB or rigid fiberglass board applied to 2 X 4 studs with the stud space filled with thermal and 1/2 inch gypsum board applied on the exposed interior side. This has a mass of about 3-4 lbs/sq ft and low 26 STC.

[16] The basis for these predictions includes reports on aircraft sound insulation for dwellings and façade sound isolation data from the Canada Research Council.

[17] "On the sound insulation of wood stud exterior walls" by J. S. Bradley and J. S. Birta, institute for Research in Construction, National Research Council, Montreal Road, Ottawa K1A 0R6, Canada, published: J.Acoust. Soc. Am. 110 (6), December 2001

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walls and roof provide a reduction of 15 dBA or more. But, that that would be misleading because it ignores the effects of low frequency sound.

We next increased the number of 2.5 Mw turbines from one to ten and moved the receiver one mile from the closest turbine. We assumed the acoustic center for the ten turbines to be 2km (1-1/4 miles) from the receiver. These results are presented in Figure 4. We were surprised to find that the one mile low frequency results are only 6.3 dB below the 1,000 foot one turbine example.

There is one other characteristic of wind turbine sound that increases the sleep disturbance potential above that of other long-term noise sources. The amplitude modulation of the sound emissions from the wind turbines create a repetitive rise and fall in sound levels synchronized to the blade rotation speed. Many common weather conditions increase the magnitude of amplitude modulation. Most of these occur at night. The graph in Figure 5 shows this effect in the first floor bedroom of a farm home in the U.K. The home is located 930 meters (3,050 feet) from the nearest turbine. The conditions documented by an independent acoustical consultant show the sound level varying over 9 dBA range from 28 to 37 dBA. The pattern repeats approximately every second often for hours at a time. For many people, especially seniors, children and those with pre-existing medical conditions, this represents a major challenge to restful sleep.

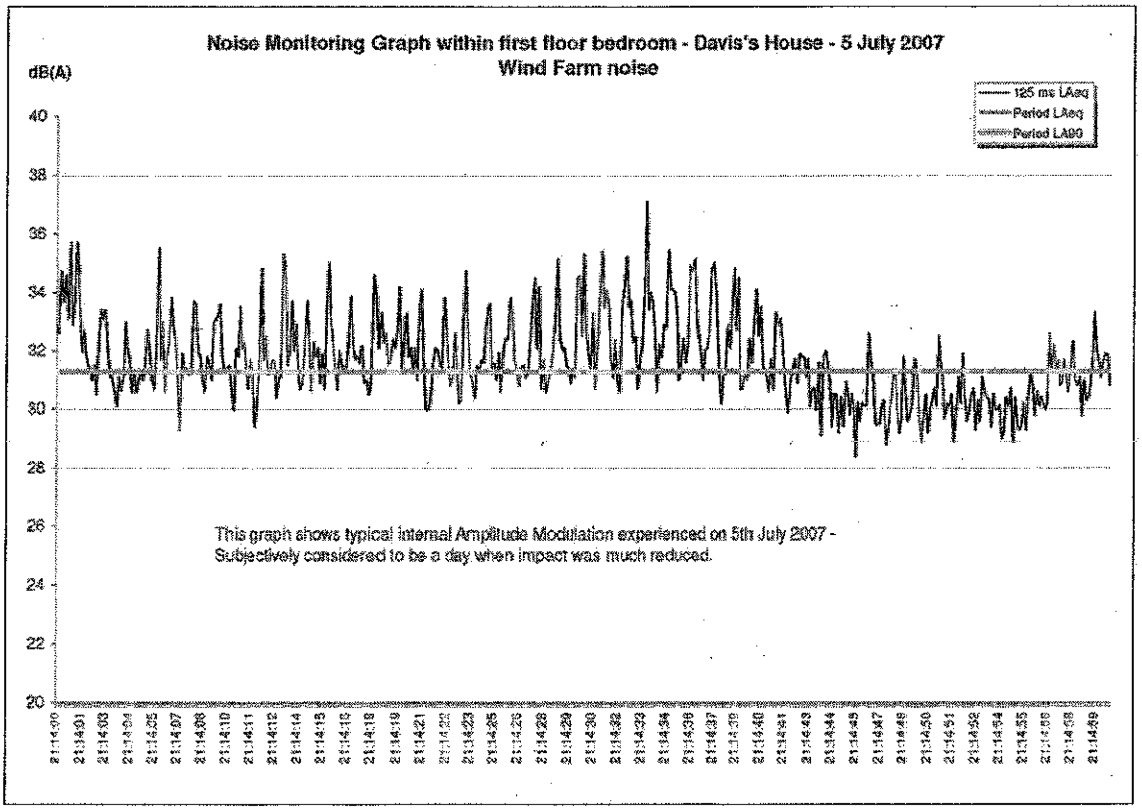

Figure 5- Amplitude modulation in a home 930 meters (3000 feet) from the nearest turbine.[19]

This may explain why some residents as far as two (2) miles from a wind farm find the wind turbines sounds highly annoying. It also demonstrates the primary reason why relying on dBA

[18] Dan Hoffmeyer, Birger Plovsing: "Low Frequency Noise from Large Wind Turbines, Measurements of Sound Insulation of Facades." Journal no. AV 1097/08, Client: Danish Energy Authority, Amaliegade 44, 1256 Copenhagen

[19] This chart used with permission of Mike Stigwood, MIOA, FRSH, MAS Environmental, U.K. and the Davis family.

alone will not work for community noise criteria. It is the low frequency phenomena associated with wind turbine emissions that makes the dBC test criteria an important part of the proposed criteria[20].

III. Development of Siting Criteria

Basis For Using L_{A90} To Determine Pre-Construction Long-Term Background Sound

We began our research into guidelines for proper siting by reviewing guidelines used in other countries to limit WT sound emissions. A recent compendium of these standards was presented in the report "Wind Turbine Facilities Noise Issues."[21] We found common ground in many of them. Some set explicit not-to-exceed sound level limits, for example, in Germany, 40 dBA nighttime in residential areas and 35 dBA nighttime in rural and other noise-sensitive areas. Other countries use the existing background sound levels for each community as the basis for establishing the sound level limits for the WES project. This second method has the advantage of adjusting the allowable limits for various background soundscapes. It makes use of a standard method for assessing background sound levels by measuring over a specified period of observation to determine the sound level exceeded 90% of the time (L_{90}) during the night. The night is important because it is the most likely time for sleep disturbance. Then, using the background sound level as the base, the WES project is allowed to increase it by 5 dBA. It is this second method (L_{90} + 5 dBA) that was adopted for the criteria in this document. It has the advantage of adjusting the criteria for each community without the need for tables of allowable limits for different community types. The focus is only on the nighttime criteria. This is because the WES will operate 24 hours a day and the nighttime limits will be the controlling limits whether or not there are other limits for daytime.

Wind turbine noise is more annoying than other noises and needs lower limits

Since many rural communities are very quiet, it is possible that some will have L_{90} values of 25 dBA or lower. This may seem extreme when compared to limits usually imposed on other sources of community noise. However, wind turbine sounds are not comparable to the more common noise sources of vehicles, aircraft, rail, and industry. Several studies have shown that annoyance to wind turbine sounds begins at levels as low as 30 dBA.[22] This is especially true in quiet rural communities that have not had previous experience with industrial noise sources. This increased sensitivity may be due to the periodic 'swoosh' from the blades in the quiet rural soundscape, or it may be more complex. In either case, it is a legitimate response to wind turbine sound documented in peer-reviewed research.

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[20] Hessler Jr., George F., "Proposed criteria in residential communities for low-frequency noise emissions from industrial sources," 52(4), 179-185, (July-Aug 2004)

[21] Ramani Ramakrishnan, Ph.D., P. Eng., "Wind Turbine Facilities Noise Issues," December 2007. Prepared for the Ontario Ministry of Environment.

[22] Eja Pedersen, "Human response to wind turbine noise: perception, annoyance and moderating factors." Dissertation, Occupational and Environmental Medicine, Department of Public Health and Community Medicine, Goteborg University, Goteborg, Sweden, 2007, and

Van den Berg F, Pedersen E, Bouma J, and Bakker R, Wind Farm Perception, Final Report Project no. 044628, University of Gothenburg and Medical Center Groningen, Netherlands June 3, 2008

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Noise criteria need to take into account low frequency noise

In the table to the right are a series of observations and recommendations by the World Health Organization (WHO) supporting the need for stricter limits when there is substantial low frequency content in outdoor sound. Our review of other studies, and our own measurements, has demonstrated that wind turbine sound includes considerable low frequency content. We include a dBC limit in our guidelines to address the WHO recommendation that when low frequency sound may be present, criteria based on measurements using a C-weighting filter on the sound level meter (dBC) are needed in addition to dBA criteria.

The World Health Organization recognizes the special place of low frequency noise as an environmental problem. Its publication "Community Noise" (Berglund et al., 2000) makes a number of references to low frequency noise, some of which are as follows:

- "It should be noted that low frequency noise... can disturb rest and sleep even at low sound levels.
- For noise with a large proportion of low frequency sounds a still lower guideline (than 30dBA) is recommended.
- When prominent low frequency components are present, noise measures based on A-weighting are inappropriate.
- Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting.
- It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health."

WHO also states: "The evidence on low frequency noise is sufficiently strong to warrant immediate concern."

Available at http://www.who.int/docstore/peh/noise/guidelines2.html, References found at pages ix, xii through xv and others.

IV. Proposed Sound Limits

The simple fact that so many residents complain of low frequency noise from wind turbines is clear evidence that the single A-weighted (dBA) noise descriptor used in most jurisdictions for siting turbines is not adequate. The only other simple audio frequency weighting that is standardized and available on sound level meters is C-weighting or dBC. A standard sound level meter set to measure dBA is increasingly less sensitive to low frequency below 500 Hz (one octave above middle-C). The same sound level meter set to measure dBC is equally sensitive to all frequencies above 32 Hz (lowest note on grand piano). It is generally accepted that dBC readings are more predictive of perceptual loudness than dBA readings if low frequency sounds are significant.

We are proposing to use the commonly accepted dBA criteria that is based on the pre-existing background sound levels allowing the wind turbine development to increase this by 5 dB (e.g. L_{90A} +5) by the audible sounds from wind turbines. According to the New York State Energy Research & Development Authority:

- "... A change in sound level of 5 dB will typically result in a noticeable community response; and
- "... A 10 dB increase is subjectively heard as an approximate doubling in loudness, and almost always causes an adverse community response." [23]

To address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC that follow the same scheme as used for dBA limits. The Proposed Sound Limits are presented in the text box at the end of this section.

For the current industrial grade wind turbines in the 1.5 to 3 MWatt (or over) range, the addition of the dBC requirement may result in an increased distance between wind turbines and the nearby

[23] (*Wind Energy Development: A Guide for Local Authorities in New York*; page 30; New York State Energy Research & Development Authority, Albany, NY October 2002)

residents. For the conditions shown in Figure 1, the distances would need to be increased significantly. This would result in setbacks in the range of 1 km or greater for the current generation of wind turbines if they are to be located in rural areas with little or no low frequency sound from man-made noise sources and where the L_{A90} background sound levels are 30 dBA or lower. In areas with higher background sound levels, turbines could be located somewhat closer, but still at a distance greater than the 305 m (1000 ft.) or smaller setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

Following are some additional Questions and Answers that summarize the major points of this discussion relevant to criteria.

What are the typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. Examples are listed above in the section on Results of Literature and Sound Studies.

What is a reasonable wind farm sound immission limit to protect the health of residences? We are proposing a not-to-exceed immission limit of 35 L_{Aeq} and a site-specific limit of L_{A90} + 5 dBA at the closest property line, whichever is exceeded first. We also propose the use of C-weighted criteria to address complaints of wind turbine low frequency noise. For the C-weighted criteria, we propose a site-specific limit of L_{C90} + 5 dBC. We also require that the site-specific L_{Ceq} (dBC) sound level at a receiving property line not exceed the pre-existing L_{A90} dB background sound level + 5dB by more than 20 dB. In other words, the dBC operating immission limit (as L_{Ceq}) at the receiving property line should not be more than 20 dB above the measured dBA (as L_{A90}) pre-construction long-term background sound level + 5dB.[24] This criterion prevents an Immission Spectra Imbalance that often leads to complaints about rumble or other low frequency problems. We also include a not-to-exceed immission limit of 55 and 60 L_{Ceq} at the receiving property line.[25] Use of the multiple metrics and weightings will address the audible and inaudible low frequency portions of wind turbine sound emissions. Exceedances of any of the limits establish non-compliance.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{A90}+5 dB? The World Health Organization and others[26] have determined that if a noise has a measured difference between dBC and dBA more than 20 dB, the noise is highly likely to create an annoyance because of the low frequency component.

Isn't L_{A90} the minimum background noise level? Not exactly. This is the sound level that represents the quietest 10% of the time. It is often considered to be the sound level that represents the sounds one hears late in the evening or at night when there are no near-by or short term sounds present. It is very important to establish this "long term background" noise environment at the property line for a potentially impacted residence (L_{A90}) during the quietest sleeping hours of the night, between 10 p.m. and 4 a.m.. Why? Because nighttime sleep disturbance has generated the majority of wind farm noise complaints throughout the world those conditions should guide the design of wind projects. ANSI standards define the "long term background sound" as excluding all short term sounds from the test sample using carefully selected sampling times and conditions using ten (10) minute long samples. This means that nature sounds not present during all seasons and wind noise are not to be included in the measurement. Following the procedures in ANSI S12.9, Part 3 for long term background sound the L_{A90} and L_{C90} can be measured with one or more 10-minute

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[24] Hessler Jr., George F., Proposed criteria in residential communities for low-frequency noise emissions from industrial sources, Noise Control Engineering Journal; 52(4), pg. 180 in "2. Purpose of Proposed Criteria," (July-Aug 2004)
[25] Ibid, pg. 180 in "3. Proposed Criteria."

[26] Ibid

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measurements during any night when the atmosphere is classified as stable with a light wind from the area of the proposed wind farm. The basis for the immission limits for the proposed wind farm would then be the Nighttime Immission Limits, which we propose to be the minimum ten (10) minute nighttime L_{A90} and L_{C90} plus 5 dB, a test for Spectra Imbalance, and not-to-exceed limits for the period of 10 p.m. to 7 a.m. Daytime Limits (7 a.m. to 10 p.m.) could be set using daytime measurements, but unless the wind utility only operates during the day, the nighttime limit will always be the limiting sound level. Thus, daytime limits are not normally needed.

A nearby industrial scale wind utility meeting these noise immission criteria would occasionally be audible to the residents during nighttime and daytime. However, it would be unlikely for it to be an indoor problem.

The method used for establishing the background sound level at a proposed wind farm in many of the studies in Table 1, does not meet the requirements set by ANSI S12.9 Part 3 for outdoor measurements and determination of long-term background sound levels. Instead, they use unattended noise monitors to record hundreds of 10-minute or one-hour un-observed measurements that include the short term sounds from varying community and wind conditions over a period of days or weeks. The results for daytime and nighttime are usually combined to determine the average wind noise at the microphone as a function of wind velocity measured at a height of ten (10) meters. This provides an enormous amount of data, but the results have little relationship to wind turbine sound immissions or to potential for turbine noise impacts on nearby residents. They also do not comply with ANSI standards for methodology or quality and as such are not suitable for use in measurements that will be used to assess compliance with other standards and guidelines. This exhaustive exercise often only demonstrates how much 'pseudo-noise' is generated by instruments located in a windy environment that exceeds the capability of the instrument's wind screen to protect the microphone. In many cases, this unqualified data is used to support a claim that the wind noise masks the turbines' sound immissions.

The major complaints of residents living near wind farms is sleep disruption at night when there is little or no wind near ground level and the wind turbines located at a much higher elevation are turning and generating near or at maximum power and maximum noise emission. There is usually more surface wind and turbulence during daytime caused by solar radiation. Thus, the use of averaged data involving one or more 24-hour periods is of little value in predicting conditions that will result in people who cannot sleep in their homes during the night because of loud intrusive wind turbine noise.

The methodology used to predict the sound propagation from the turbines into the community also fails to represent the conditions of maximum turbine noise impact on nearby residents. This should be expected given the limitations of models based on ISO 9613-2[27]. They also do not consider the effects of a frequent nighttime condition when winds at the ground are calm and the winds at the hub are at or above nominal operating speed. This condition is often referred to as a "stable" atmosphere. During this condition, the wind turbines can be producing the maximum or near maximum power while the wind at ground level is calm and the background noise level is low. The Michigan rural night test data in the earlier figure shows how quiet a night can be in the absence of wind at the ground. This common condition is known to directly cause chronic sleep

[27] The ISO 9613-2 sound propagation model formulas have known errors of 3 dB even when the conditions being modeled are a perfect match to the limiting conditions specified in the standard. Wind turbines operate far outside the limits for wind speed, height of the noise source above the ground, and other factors identified in the standard thus increasing the likelihood for error above the specified 3 dB. In addition, there are known measurement errors in the IEC61400-11 test that add another 2 dB of uncertainty to the model's predictions.

disruption. Further, the studies report average sound levels and do not disclose the effects of amplitude modulation or low frequency sound which makes the turbine's sound more objectionable and likely to cause sleep problems.

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes. The precision measuring sound level meter(s) need to be programmed to include measurement of L_{Aeq}, L_{A10}, L_{A90}, L_{Ceq}, L_{C10}, and L_{C90}, with starting time and date for each 10-minute sample. The L_{10} results will be used to validate the L_{90} data. For example, on a quiet night one might expect L_{10} and L_{90} to show similar results within 5 to 10 dB between L_{10} and L_{90} for each weighting scale. On a windy night or one with nearby short term noise sources the difference between L_{10} and L_{90} may be more than 20 dB. There is also often a need to obtain a time-averaged, one-third octave band analysis over the frequency range from 6.3 Hz to 10 kHz during the same ten minute sample. The frequency analysis is very helpful for identifying and correcting for extraneous sounds such as interfering insect noise. An integrating averaging sound level meter meeting ANSI or IEC Type 1 standards has the capability to perform all of the above acoustic measurements simultaneously and store the results internally. There is also a requirement for measurement of the wind velocity near the sound measurement microphone continuously throughout each 10-minute recorded noise sample. The 10-minute maximum wind speed near the microphone must be less than 2 m/s (4.5 mph) during measurements of background noise (L_{90}), and the maximum wind speed for noise measurements during turbine operation must be less than 4 m/s (9 mph). Measurements should be observed (without contaminating the data) and notes identifying short-term noises should be taken for these tests.

Is there a need to record weather data during the background noise recording survey? One weather monitor is required at the proposed wind farm on the side nearest the residents. The weather station sensors are at the standard 10 meter height above ground. It is critical that the weather be recorded every 10 minutes, synchronized with the clocks in the sound level recorders without ambiguity, at the start and end time of each 10 minute period. The weather station should record wind speed and direction, temperature, humidity and rain.

Why do Canada and some other countries base the permitted wind turbine noise immission limits on the operational wind velocity at the 10m height wind speed instead of a maximum dBA or L_{90} + 5 dBA immission level? First, it appears that the wind turbine industry will take advantage of every opportunity to elevate the maximum permitted noise immission level to reduce the setback distance from the nearby dwellings. Including wind as a masking source in the criteria is one method for elevating the permissible limits. The background noise level does indeed increase with surface wind speed. When this happens, it can be argued that the increased wind noise provides some masking of wind turbine noise. However, this is not true if the surface winds are calm. After sunset, when the ground cools (e.g. in the middle of the night), the lower level atmosphere can separate from the higher-level atmosphere. Then, the winds at the ground will be calm while wind at the turbine hub is very strong. Under this condition, the wind velocity at a 10-meter high wind monitoring station (such as those often used for weather reporting) may be ¼ to ½ the speed of the wind at the hub, yet drop to calm at ground level. The result is that no ground level wind noise is present to mask the sound of the wind turbines, which can be operating at or close to full capacity.

This condition is one of the major causes of wind turbine related noise complaints for residents within 3 km (1.86 miles) of a wind farm. When the turbines are producing high sound levels, it is quiet outside the surrounding homes. The PhD thesis of G.P. van den Berg, *The Sounds of High*

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Winds, is very enlightening on this issue (Table 3). See also the letter by John Harrison in Ontario "On Wind Turbine Guidelines.[28]"

What sound monitor measurements would be needed for enforcement of the wind turbine sound ordinance? A similar set of sound tests using the ten (10) minute series of measurements would be repeated, with and without the operation of the wind turbines, at the location where noise was measured before construction, which is closest to the resident registering the wind turbine noise complaint. If the nighttime background (L_{90}) noise level (turbines off) was found to be slightly higher than the measured background prior to the wind farm installation, then the results with the turbines operating must be corrected using standard acoustical engineering methods to determine compliance with the pre-turbine established sound limits.

Who should conduct the sound measurements? An independent acoustics expert should be retained who reports to the County Board or other responsible governing body. This independent acoustics expert should be responsible for all the acoustic measurements including setup and calibration of instruments and interpretation of recorded results. He or she should perform all pre-turbine background noise measurements and interpretation of results to establish the nighttime (and daytime, if applicable) industrial wind turbine sound immission limits, and to monitor compliance.

At present, the acoustical consultants are retained by, and work directly for, the wind farm developers. This presents a serious problem with conflict of interest on the part of the consultants. The wind farm developer would like to show that a significant amount of wind noise is present to mask the sounds of the wind turbine immissions. The community is looking for authentic results showing that the wind turbine noise will be only barely perceptible, and then only occasionally, during the night or daytime.

Is frequency analysis required either during the pre-construction background noise survey or for compliance measurements? Normally one-third octave or narrower band analysis would only be required if there is a complaint of tones immission from the wind farm. Although only standardized dBA and dBC measurements are required to meet the proposed criteria, the addition of one-third octave band analysis is often useful to validate the dBA and dBC results.

The following summarizes the criteria necessary when siting wind turbines to minimize the risk of adverse impacts from noise on the adjacent community[29]. For those not familiar with acoustical annotation the table and its formulas may seem overly complex, but the criteria are defined in this manner to be as unambiguous as possible. They will be clear for those who are familiar with acoustical terminology. Definitions are provided in a later section of this essay.

[28] Harrison, J., *Wind Turbine Guidelines,* available at http://amherstislandwindinfo.com/

[29] The authors have based these criteria, procedures, and language on their current understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. However, use of the following, in part or total, by any party is strictly voluntary and the user assumes all risks. Please seek professional assistance in applying the recommendations of this document to any specific community or WES development.

NOISE CRITERIA FOR SITING WIND TURBINES TO PREVENT HEALTH RISKS[29]

1. Establishing Long-Term Background Noise Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9, Part 3 except as noted in Section 4. below.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles.

c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured wind speed at the microphone is less than 2 m/s (4.5 mph).

d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC data includes L_{C90}, L_{C10}, and L_{Ceq}. Record the maximum wind speed at the microphone during the ten minutes, a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is oftener shall also be recorded. A ten (10) minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone is less than 2 m/s during the same ten (10) minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located so as to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-To-Exceed Property Line Sound Immission Limits [1]

Criteria	Condition	dBA	dBC
A	Immission above pre-construction background:	$L_{Aeq} = L_{A90} + 5$	$L_{Ceq} = L_{C90} + 5$
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance	L_{Ceq} (immission) minus (L_{A90} (background) +5) $\leq$ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB
Notes			
1	Each Test is independent and exceedances of any test establishes non-compliance. Sound "immission" is the wind turbine noise emission as received at a property.		
2	A "Quiet rural environment" is a location >2 miles from a major transportation artery without high traffic volume during otherwise quiet periods of the day or night.		
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.		

[1] Procedures provided in Section 7. Measurement Procedures (ANSI 12.9 Part 3 with Amendments) of the most recent version of **"The How To Guide To Siting Wind Turbines To Prevent Health Risks From Sound"** by Kamperman and James and the apply to this table.

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing Nighttime Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearer to the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9- Part 3 apply except as noted in Section 4. The effect of instrumentation limits for wind and other factors must be recognized and followed.

4. ANSI S12.9 Part 3 Selected Options and Requirement Amendments

For measurements taken to assess the preceding criteria specific options provided for in ANSI S12.9-Part 3 (2008) shall be followed along with any additional requirements included below:

5.2 Background Sound: Use definition (1): 'long-term'

5.2 long-term background sound: The L_{90} excludes short term background sounds

5.3 basic measurement period: Ten (10) minutes $L_{90(10\ min)}$

5.6 Sound Measuring Instrument: Type 1 Precision meeting ANSI S1.43 or IEC 61672-1. The sound level meter shall cover the frequency range from 6.3 Hz to 20k Hz and simultaneously measure dBA L_N and dBC L_N. The instrument must also be capable of accurately measuring low-level background sounds down to 20 dBA.

6.5 Windscreen: Required

6.6(a) An anemometer accurate to ± 10% at 2m/s to full-scale accuracy. The anemometer shall be located 1.5 to 2 meters above the ground and orientated to record maximum wind velocity. The maximum wind velocity, wind direction, temperature and humidity shall be recorded for each ten (10) minute sound measurement period observed within 5 m. of the measuring microphone.

7.1 Long-term background sound

7.2 Data collection Methods: Second method with observed samples to avoid contamination by short term sounds (purpose: to avoid loss of statistical data)

8. Source(s) Data Collection: All requirements in ANSI S12.18 Method #2, Precision to the extent possible while still permitting testing of the conditions that lead to complaints. The meteorological requirements in ANSI S12.18 may not be applicable for some complaint tests. For sound measurements in response to a complaint, the compliance sound measurements should be made under conditions that replicate the conditions that caused the complaint without exceeding instrument and windscreen limits and tolerances.

8.1(b) Measuring microphone with windscreen shall be located 1.2m to 1.8m (1.5 preferred) above the ground and greater than 8 m. from large sound reflecting surface.

8.3(a) All meteorological observations required at both (not either) microphone and nearest 10 m. weather reporting station.

8.3(b) For a ten (10) minute background sound measurement to be valid the wind velocity shall be less then 2m/s (4.5 mph) measured less than 5 m. from the microphone. Compliance sound measurements shall be taken when winds are less than 4m/s at the microphone.

8.3(c) In addition to the required acoustic calibration checks, the sound measuring instrument internal noise floor, including microphone, must also be checked at the end of each series of ten minute measurements and no less frequently than once per day. Insert the microphone into the acoustic calibrator with the calibrator signal off. Record the observed dBA and dBC reading on the sound level meter to determine an approximation of the instrument self noise. Perform this test before leaving the background measurement location. The calibrator-covered microphone must demonstrate the results of this test are at least 5 dB below the immediately previous ten (10) minute acoustic test results, for the acoustic background data to be valid. This test is necessary to detect undesired increase in the microphone and sound level meter internal self-noise. As a precaution sound measuring instrumentation should be removed from any air conditioned space at least an hour before use. Nighttime measurements are often performed very near the meteorological dew point. Minor moisture condensation inside a microphone or sound level meter can increase the instrument self noise and void the measured background data.

8.4 The remaining sections, starting at 8.4 in ANSI S12.9 Part 3 Standard do not apply.

V. How to Include the Recommended Criteria in Ordinances and/or Community Noise Limits

The following two sections present the definitions, technical requirements, and complaint resolution processes that support the recommended criteria. Following the formal elements is a section discussing the measurement procedures and requirements for enforcement of these criteria. For the purpose of the following sections the government authority will be referred to as the Local Government Authority (LGA) as a place marker for State, County, Township or other authorized authority. The abbreviation 'WES' is used for industrial scale wind energy system.

The authors have based these criteria, procedures, and language on their current understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. However, use of the following, in part or total, by any party is strictly voluntary and the user assumes all risks. Please seek professional assistance in applying the recommendations of this document to any specific community or WES development.

VI. ELEMENTS OF A WIND ENERGY SYSTEMS LICENSING ORDINANCE FOR SOUND

I. Purpose and Intent.

Based upon the findings stated above, it is the intended purpose of the LGA to regulate Wind Energy Systems to promote the health, safety, and general welfare of the citizens of the Town and to establish reasonable and uniform regulations for the operation thereof so as to control potentially dangerous effects of these Systems on the community.

II. Definitions.

The following terms have the meanings indicated:

"**Aerodynamic Sound**" means a noise that is caused by the flow of air over and past the blades of a WES.

"**Ambient Sound**" Ambient sound encompasses all sound present in a given environment, being usually a composite of sounds from many sources near and far. It includes intermittent noise events, such as, from aircraft flying over, dogs barking, wind gusts, mobile farm or construction machinery, and the occasional vehicle traveling along a nearby road. The ambient also includes insect and other nearby sounds from birds and animals or people. The near-by and transient events are part of the ambient sound environment but are <u>not to be considered part of the long-term background sound.</u>

"**American National Standards Institute (ANSI)**" Standardized acoustical instrumentation and sound measurement protocol shall meet all the requirements of the following ANSI Standards:

ANSI S1.43 Integrating Averaging Sound Level Meters: Type-1 (or IEC 61672-1)

ANSI S1.11 Specification for Octave and One-third Octave-Band Filters (or IEC 61260)

ANSI S1.40 Verification Procedures for Sound Calibrators

ANSI S12.9 Part 3 Procedures for Measurement of Environmental Sound

ANSI S12.18 Measurement of Outdoor Sound Pressure Level

IEC 61400-11 Wind turbine generator systems -Part 11: Acoustic noise measurements

"**Anemometer**" means a device for measuring the speed and direction of the wind.

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"**Applicant**" means the individual or business entity that seeks to secure a license under this section of the Town municipal code.

"**A-Weighted Sound Level (dBA)**" A measure of over-all sound pressure level designed to reflect the response of the human ear, which does not respond equally to all frequencies. It is used to describe sound in a manner representative of the human ear's response. It reduces the effects of the low with respect to the frequencies centered around 1000 Hz. The resultant sound level is said to be "A-weighted" and the units are "dBA." Sound level meters have an A-weighting network for measuring A-weighted sound levels (dBA) meeting the characteristics and weighting specified in ANSI Specifications for Integrating Averaging Sound Level Meters, S1.43-1997 for Type 1 instruments and be capable of accurate readings (corrections for internal noise and microphone response permitted) at 20 dBA or lower. In this document dBA means L_{Aeq} unless specified otherwise.

"**Background Sound (L_{90})**" refers to the sound level present at least 90% of the time. Background sounds are those heard during lulls in the ambient sound environment. That is, when transient sounds from flora, fauna, and wind are <u>not</u> present. Background sound levels vary during different times of the day and night. Because WES operates 24/7 the background sound levels of interest are those during the quieter periods which are often the evening and night. Sounds from the WES of interest, near-by birds and animals or people must be excluded from the background sound test data. Nearby electrical noise from streetlights, transformers and cycling AC units and pumps etc must also be excluded from the background sound test data.

Background sound level (dBA and dBC (as L_{90})) is the sound level present 90% of the time during a period of observation that is representative of the quiet time for the soundscape under evaluation and with duration of ten (10) continuous minutes. Several contiguous ten (10) minute tests may be performed in one hour to determine the statistical stability of the sound environment. Measurement periods such as at dusk when bird and insect activity is high or the early morning hours when the 'dawn chorus' is present are not acceptable measurement times. Longer term sound level averaging tests, such as 24 hours or multiple days are not at all appropriate since the purpose is to define the quiet time background sound level. It is defined by the L_{A90} and L_{C90} descriptors. ~~It may be considered as the quietest one (1) minute during a ten (10) minute test.~~ L_{A90} results are valid only when L_{A10} results are no more than 10 dB above L_{A90} for the same period. L_{C10} less L_{C90} are not to exceed 10 dB to be valid.

The background noise environment consists of a multitude of distant sources of sound. When a new nearby source is introduced the new background noise level would be increased. The addition of a new source with a noise level 10 below the existing background would increase the new background 0.4 dB. If the new source has the same noise level as the existing background then the new background is increased 3.0 dB. Lastly, if the new source is 3.3 dB above the existing background then the new background would have increased 5 dB. For example, to meet the requirement of L_{90A} + 5 dB = 31 dBA if the existing quiet nighttime background sound level is 26 dBA, the maximum wind turbine noise immission contribution independent of the background cannot exceed 29.3 dBA L_{eq} at a dwelling. When adding decibels, a 26 dBA background combined with 29.3 dBA from the turbines (without background) results in 31 dBA.

Further, background L_{90} sound levels documenting the pre-construction baseline conditions should be determined when the ten (10) minute maximum wind speed is less than 2 m/s (4.5 mph) near ground level/microphone location 1.5 m height.

"**Blade Passage Frequency**" (BPF) means the frequency at which the blades of a turbine pass a particular point during each revolution (e.g. lowest point or highest point in rotation) in terms of events per second. A three bladed turbine rotating at 28 rpm would have a BPF of 1.4 Hz. [E.g. ((3 blades times 28rpm)/60 seconds per minute = 1.4 Hz BPF)]

"C-Weighted Sound Level (dBC)" Similar in concept to the A-Weighted sound Level (dBA) but C-weighting does not de-emphasize the frequencies below 1k Hz as A-weighting does. It is used for measurements that must include the contribution of low frequencies in a single number representing the entire frequency spectrum. Sound level meters have a C-weighting network for measuring C-weighted sound levels (dBC)meeting the characteristics and weighting specified in ANSI S1.43-1997 Specifications for Integrating Averaging Sound Level Meters for Type 1 instruments. In this document dBC means L_{Ceq} unless specified otherwise.

"Decibel (dB)" A dimensionless unit which denotes the ratio between two quantities that are proportional to power, energy or intensity. One of these quantities is a designated reference by which all other quantities of identical units are divided. The sound pressure level (Lp) in decibels is equal to 10 times the logarithm (to the base 10) of the ratio between the pressure squared divided by the reference pressure squared. The reference pressure used in acoustics is 20 MicroPascals.

"Emission" Sound energy that is emitted by a noise source (wind farm) is transmitted to a receiver (dwelling) where it is immitted (see "immission).

"Frequency" The number of oscillations or cycles per unit of time. Acoustical frequency is usually expressed in units of Hertz (Hz) where one Hz is equal to one cycle per second.

"Height" means the total distance measured from the grade of the property as existed prior to the construction of the wind energy system, facility, tower, turbine, or related facility at the base to its highest point.

"Hertz (Hz)" Frequency of sound expressed by cycles per second.

"Immission" Noise immitted at a receiver (dwelling) is transmitted from noise source (wind turbine) that emitted sound energy (see "emission").

"Immission spectra imbalance" The spectra are not in balance when the C-weighted sound level is more than 20 dB greater than the A-weighted sound level. For the purposes of this requirement, the A-weighted sound level is defined as the long-term background sound level (L_{A90}) +5 dBA. The C-weighted sound level is defined as the L_{Ceq} measured during the operation of the wind turbine operated so as to result in its highest sound output. A Complaint test provided later in this document is based on the immission spectra imbalance criteria.

"Infra-Sound" sound with energy in the frequency range of 0-20 Hz is considered to be infra-sound. It is normally considered to not be audible for most people unless in relatively high amplitude. However, there is a wide range between the most sensitive and least sensitive people to perception of sound and perception is not limited to stimulus of the auditory senses. The most significant exterior noise induced dwelling vibration occurs in the frequency range between 5 Hz and 50 Hz. Moreover, levels below the threshold of audibility can still cause measurable resonances inside dwelling interiors. Conditions that support or magnify resonance may also exist in human body cavities and organs under certain conditions. Although no specific test for infrasound is provided in this document, the test for immission spectra imbalance will limit low frequency sound and thus, indirectly limit infrasound. See low-frequency noise (LFN) for more information.

"Low Frequency Noise (LFN)" refers to sounds with energy in the lower frequency range of 20 to 200 Hz. LFN is deemed to be excessive when the difference between a C-weighted sound level and an A-weighted sound level is greater than 20 decibels at any measurement point outside a residence or

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other occupied structure. The criteria for this condition is the "Immission Spectra Imbalance" entry in the **Table of Not-To-Exceed Property Line Sound Immission Limits.**"

"**Measurement Point (MP)**" means location where sound measurements are taken such that no significant obstruction blocks sound from the site. The Measurement Point should be located so as to not be near large objects such as buildings and in the line-of-sight to the nearest turbines. Proximity to large buildings or other structures should be twice the largest dimension of the structure, if possible. Measurement Points should be at quiet locations remote from street lights, transformers, street traffic, flowing water and other local noise sources.

"**Measurement Wind Speed**" For measurements conducted to establish the background noise levels ($L_{A90\ 10\ min}$, $L_{C90\ 10\ min}$, and etc.) the maximum wind speed, sampled within 5m of the microphone and at its height, shall be less than 2 m/s (4.5 mph) for valid background measurements. For valid wind farm noises measurements conducted to establish the post-construction sound level the maximum wind speed, sampled within 5m of the microphone and at its height, shall be less than 4m/s (9 mph). The wind speed at the WES blade height shall be at or above the nominal rated wind speed and operating in its highest sound output mode. For purposes of enforcement, the wind speed and direction at the WES blade height shall be selected to reproduce the conditions leading to the enforcement action while also restricting maximum wind speeds at the microphone to less than 4 m/s (9 mph).

For purposes of models used to predict the sound levels and sound pressure levels of the WES to be submitted with the Application, the wind speed shall be the speed that will result in the worst-case L_{Aeq} and L_{Ceq} sound levels at the nearest non-participating properties to the WES. If there may be more than one set of nearby sensitive receptors, models for each such condition shall be evaluated and the results shall be included in the Application.

"**Mechanical Noise**" means sound produced as a byproduct of the operation of the mechanical components of a WES(s) such as the gearbox, generator and transformers.

"**Noise**" means any unwanted sound. Not all noise needs to be excessively loud to represent an annoyance or interference.

"**Project Boundary**" means the external property boundaries of parcels owned by or leased by the WES developers. It is represented on a plot plan view by a continuous line encompassing all WES(s) and related equipment associated with the WES project.

"**Property Line**" means the recognized and mapped property parcel boundary line.

"**Qualified Independent Acoustical Consultant**" Qualifications for persons conducting baseline and other measurements and reviews related to the application for a WES or for enforcement actions against an operating WES include, at a minimum, demonstration of competence in the specialty of community noise testing. An example is a person with Full Membership in the Institute of Noise Control Engineers (INCE). There are scientists and engineers in other professional fields that have been called upon by their local community for help in the development of a WES Noise Ordinance. Many of these scientists and engineers have recently spent hundreds of hours learning many important aspects of noise related to the introduction of WES into their communities. Then with field measurement experience with background data and wind turbine noise emission, they have become qualified independent acoustical consultants for WES siting. Certifications such as Professional Engineer (P.E.) do not test for competence in acoustical principles and measurement and are thus not, without further qualification, appropriate for work under this document. The Independent Qualified Acoustical Consultant can have no financial or other connection to a WES developer or related company.

"**Sensitive Receptor**" means places or structures intended for human habitation, whether inhabited or not, public parks, state and federal wildlife areas, the manicured areas of recreational establishments designed for public use, including but not limited to golf courses, camp grounds and other nonagricultural state or federal licensed businesses. These areas are more likely to be sensitive to the exposure of the noise, shadow or flicker, etc. generated by a WES or WESF. These areas include, but are not limited to: schools, daycare centers, elder care facilities, hospitals, places of seated assemblage, non-agricultural businesses and residences.

"**Sound**" A fluctuation of air pressure which is propagated as a wave through air

"**Sound Power**" The total sound energy radiated by a source per unit time. The unit of measurement is the watt. Abbreviated as L_w. This information is determined for the WES manufacturer under laboratory conditions specified by IEC 61400-11 and provided to the local developer for use in computer model construction. There is known measurement error in this test procedure that must be disclosed and accounted for in the computer models. Even with the measurement error correction it cannot be assumed that the reported L_w values represent the highest sound output for all operating conditions. They reflect the operating conditions required to meet the IEC 61400-11 requirements. The lowest frequency is 50 Hz for acoustic power (L_w) requirement (at present) in IEC 61400-11. This Ordinance requires wind turbine certified acoustic power (L_w) levels at rated load for the total frequency range from 6.3 Hz to 10k Hz in one-third octave frequency bands tabulated to the nearest 1 dB. The frequency range of 6.3 Hz to 10k Hz shall be used throughout this Ordinance for all sound level modeling, measuring and reporting.

"**Sound Pressure**" The instantaneous difference between the actual pressure produced by a sound wave and the average or barometric pressure at a given point in space.

"**Sound Pressure Level (SPL)**" 20 times the logarithm, to the base 10, of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micronewtons per square meter. In equation form, sound pressure level in units of decibels is expressed as SPL (dB) = 20 log p/pr.

"**Spectrum**" The description of a sound wave's resolution into its components of frequency and amplitude. The WES manufacturer is required to supply a one-third octave band frequency spectrum of the wind turbine sound emission at 90% of rated power. The published sound spectrum is often presented as A-weighted values but C-weighted values are preferred. This information is used to construct a model of the wind farm's sound immission levels at locations of interest in and around the WES. The frequency range of interest for wind turbine noise is approximately 6 Hz to 10k Hz.

"**Statistical Noise Levels**" Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{NA}, where L_{NA} is the A-weighted sound level exceeded for N% of a given measurement period. For example, L_{10} is the noise level exceeded for 10% of the time. Of particular relevance, are: L_{A10} and L_{C10} the noise level exceed for 10% of the ten (10) minute interval. This is commonly referred to as the average maximum noise level. L_{A90} and L_{C90} are the A-weighted and C-weighted sound levels exceeded for 90% of the ten (10) minute sample period. The L_{90} noise level is defined by ANSI as the long-term background sound level (i.e. the sounds one hears in the absence of the noise source under consideration and without short term or near-by sounds from other sources), or simply the "background level." L_{eq} is the A or C-weighted equivalent noise level (the "average" noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

"Tonal sound or tonality" Tonal audibility. A sound for which the sound pressure is a simple sinusoidal function of the time, and characterized by its singleness of pitch. Tonal sound can be simple or complex.

"Wind Energy Systems (WES)" means equipment that converts and then transfers energy from the wind into usable forms of electrical energy.

"Wind Turbine" or "Turbine" (WT) means an industrial scale mechanical device which captures the kinetic energy of the wind and converts it into electricity. The primary components of a wind turbine are the blade assembly, electrical generator and tower.

III. APPLICATION PROCEDURE FOR WIND ENERGY SYSTEMS AND TECHNICAL REQUIREMENTS FOR LICENSING

This ordinance is intended to promote the safety and health of the community through criteria limiting sound emissions during operation of Wind Energy Systems. It is recognized that the requirements herein are neither exclusive, nor exhaustive. In instances where a health or safety concern is known to the wind project developer or identified by other means with regard to any application for a Wind Energy System, additional and/or more restrictive conditions may be included in the license to address such concerns. All rights are reserved to impose additional restrictions as circumstances warrant. Such additional or more restrictive conditions may include, without limitation (a) greater setbacks, (b) more restrictive noise limitations, or (c) limits restricting operation during night time periods or for any other conditions deemed reasonable to protect the community.

A. Application

Any Person desiring to secure a Wind Energy Systems license shall file an application form provided by the LGA Clerk, together with two additional copies of the application with the LGA Clerk.

B. Information to be submitted with Application

1. Information regarding the:

- Make and model of all turbines potentially used in this project,
- Sound Power Levels (L_w) for each 1/3 octave band from 6.3 Hz to 10,000 Hz, and
- A sound propagation model predicting the sound levels immitted into the community computed using at minimum 1/1 octave band sound power levels to compute the L_{Ceq} and L_{Aeq} levels to generate L_{Aeq} and L_{Ceq} contours in 5 dB increments overlaying an aerial view and property survey map from the WES property out to a distance to include all residential property within two (2) miles of the WES Property. Appropriate corrections for model algorithm error, IEC61400-11 test measurement accuracy, and directivity patterns of for each model of WT shall be disclosed and accounted for in the model(s). Predictions shall be made at all property lines within and outward for two (2) miles from the project boundary for the wind speed, direction and operating mode that would result in the worst case WT nighttime sound emissions.

The prediction model shall assume that the winds at hub height are sufficient for the highest sound emission operating mode. The projection shall include a description of all assumptions made in the model's construction and algorithms. If the model does not consider the effects of wind direction, geography of the terrain, and/or the effects of reinforcement from coherent sounds or tones from the turbines all these items should be identified and all other means used to adjust the model's output to account for these factors. The results shall be displayed as a contour map of the predicted levels as over-all L_{Aeq} and L_{Ceq} contours out to 2 miles from the WES property, and shall also include a table showing the 1/3 or 1/1 octave band sound pressure as L_{Ceq} levels for the nearest property line(s) for sensitive receptor sites (including residences) within the model's boundaries. The predicted values must include the over-all sound levels and 1/1 or 1/3 octave band sound pressure levels from 6 Hz to 10k Hz in data tables that include the location of each receiving point by GPS location or other repeatable means.

C. Preconstruction Background Noise Survey

1. The Town reserves the right to require the preparation of (a) a preconstruction noise survey for each proposed Wind Turbine location conducted per procedures provided in the section on Measurement Procedures showing long-term background L_{A90} and L_{C90} sound levels. This must be completed and accepted prior to approval of the final layout and issuance of project permits.

    a. If any proposed wind farm project locates a WES within two miles of a sensitive receptor these studies are mandatory. The preconstruction baseline studies shall be conducted by an Independent Qualified Acoustical Consultant selected and hired by the LGA.

    b. The applicant shall be responsible for paying the consultant's fees and costs associated with conducting the study. These fees and cost shall be negotiated with the consultant and determined prior to any work being done on the study. The applicant shall be required to set aside 100% of these fees in an escrow account managed by the LGA, before the study is commenced by the consultant. Payment for this study does not require the WES developer's acceptance of the study's results.

    c. If the review shows that the predicted L_{Aeq} and L_{Ceq} sound levels exceed any of the criteria specified in the **Table of Not-To-Exceed Property Line Sound Immission Limits** then the application cannot be approved.

2. The LGA will refer the application to the LGA engineer (if qualified in acoustics) or an independent qualified acoustical consultant for further review and comparison of the long-term background sound levels against the predicted L_{Aeq} and L_{Ceq} sound levels reported for the model using the criteria in the **Table of Not-To-Exceed Property Line Sound Immission Limits.** The reasonably necessary costs associated with such a review shall be the responsibility of the applicant, in accord with the terms of this ordinance.

D. Post Construction Noise Measurement Requirements

1. **Sound Regulations Compliance:** A WES shall be considered in violation of the conditional use permit unless the applicant demonstrates that the project complies with all sound level limits using the procedures specified in this ordinance. Sound levels in excess of the limits established in this ordinance shall be grounds for the LGA to order immediate shut down of all non-compliant WT units.

2. **Post-Construction Sound Measurements:** Within twelve months of the date when the project is fully operational, and within four weeks of the anniversary date of the pre-construction background noise measurements, repeat the existing sound environment measurements taken before the project approval. Post-construction sound level measurements shall be taken both with all WES's running and with all WES's off. At the discretion of the Town, the Pre-construction background sound levels (L_{A90} and L_{C90}) can be substituted for the "all WES off' tests if a random sampling of 10% of the pre-construction study sites shows that background L_{90A} and L_{90C} conditions have increased less than 3 dB from those measured under the pre-

construction nighttime conditions. The post-construction measurements will be reported to the LGA (available for public review) using the same format as used for the preconstruction sound studies. Post-construction noise studies shall be conducted by a firm chosen and hired by the LGA. Costs of these studies are to be reimbursed by the Licensee in a similar manner to that described above. The wind farm developer's may ask to have its own consultant observe the publicly retained consultant at the convenience of the latter. The WES Licensee shall provide all technical information and wind farm data required by the qualified independent acoustical consultant before, during, and/or after any acoustical studies required by this document and for acoustical measurements.

3. Sound Limits

1. Establishing Long-Term Background Sound Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9, Part 3 and Measurement Procedures Appendix to Ordinance following next Section.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles.

c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured maximum wind speed at the microphone must be less than 2 m/s (4.5 mph).

d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC data includes L_{C90}, L_{C10}, and L_{Ceq}. The maximum wind speed at the microphone during the ten minutes, a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is oftener shall also be recorded. A ten (10) minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone is less than 2 m/s during the same ten (10) minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located so as to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-To-Exceed Property Line Sound Immission Limits [1]			
Criteria	Condition	dBA	dBC
A	Immission above pre-construction background:	$L_{Aeq} = L_{A90} + 5$	$L_{Ceq} = L_{C90} + 5$
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance (C - A $\leq$ 20dB)	L_{Ceq} (immission) minus (L_{A90} (background) +5 dB) $\leq$ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB
Notes			
1	Each Test is independent and exceedances of any test establishes non-compliance Sound "immission" is the wind turbine sound emission as received at a property.		
2	A "quiet rural environment" is a location 2 miles from a major transportation artery without high traffic volume during otherwise quiet periods of the day or night.		
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.		
[1] Required Procedures provided in VIII Reference Standards including ANSI 12.9 Part 3 as Amended			

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing Long Term Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearer to the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9- Part 3 apply as amended in the Appendix to Ordinance. The effect of instrumentation limits for wind and other factors must be recognized and followed.

3. Operations

The WES/WT is non-compliant and must be shut down immediately if it exceeds any of the limits in the **Table of Not-To-Exceed Property Line Sound Immission Limits.**

4. Complaint Resolution

1. The owner/operator of the WES shall respond within five (5) business days after notified of a noise complaint by any property owner within the project boundary and a one-mile radius beyond the project boundary.
2. The tests shall be performed by a qualified independent acoustical consultant acceptable to the complainant and the local agency charged with enforcement of this ordinance.
3. Testing shall commence within ten (10) working days of the request. If testing cannot be initiated within ten (10) days, the WES(s) in question shall be shut down until the testing can be started.
4. A copy of the test results shall be sent to the property owner, and the LGA's Planning or Zoning department within thirty (30) days of test completion.
5. If a Complaint is made, the presumption shall be that it is reasonable. The LGA shall undertake an investigation of the alleged operational violation by a qualified individual mutually acceptable to the LGA.

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a) The reasonable cost and fees incurred by the LGA in retaining said qualified individual shall be reimbursed by the owner of the WESF.

b) Funds for this assessment shall be paid or put into an escrow account prior to the study and payment shall be independent of the study findings.

6. After the investigation, if the LGA reasonably concludes that operational violations are shown to be caused by the WESF, the licensee/operator/owner shall use reasonable efforts to mitigate such problems on a case-by-case basis including such measures as not operating during the nighttime or other noise sensitive period if such operation was the cause of the complaints.

5. Reimbursement of Fees and Costs.

Licensee/operator/owner agrees to reimburse the LGA 's reasonable fees and costs incurred in the preparation, negotiation, administration and enforcement of this Ordinance, including, without limitation, the LGA 's attorneys' fees, engineering and/or consultant fees, LGA meeting and hearing fees and the costs of public notices. If requested by the LGA the funds shall be placed in an escrow account under the management of the LGA. The preceding fees are payable within thirty (30) days of invoice. Unpaid invoices shall bear interest at the rate of 1% per month until paid. The LGA may recover all reasonable costs of collection, including attorneys' fees.

VII. MEASUREMENT PROCEDURES

SUPPLEMENT TO WIND ENERGY SYSTEMS LICENSING ORDINANCE FOR SOUND

I. Introduction

The potential impact of sound and sound induced building vibration associated with the operation of wind powered electric generators is often a primary concern for citizens living near proposed wind energy systems (WES(s)). This is especially true of projects located near homes, residential neighborhoods, businesses, schools, and hospitals in quiet residential and rural communities. Determining the likely sound and vibration impacts is a highly technical undertaking and requires a serious effort in order to collect reliable and meaningful data for both the public and decision makers.

This protocol is based in part on criteria published in American National Standards S12.9 –Part 3 Quantities and Procedures for Description and Measurement of Environmental Sound, and S12.18 and for the measurement of sound pressure level outdoors.

The purpose is to first, establish a consistent and scientifically sound procedure for evaluating existing background levels of audible and low frequency sound in a WES project area, and second to use the information provided by the Applicant in its Application showing the predicted over-all sound levels in terms of L_{Aeq} and L_{Ceq} and 1/3 or 1/1 octave bands as part of the required information submitted with the application.

The over-all values shall be presented as overlays to the applicant's iso-level plot plan graphics and, for 1/1 or 1/3 octave data, in tabular form with location information sufficient to permit comparison of the baseline results to the predicted levels. This comparison will use the level limits of the ordinance to determine the likely impact operation of a new wind energy system project will have on the existing community soundscape. If the comparison demonstrates that the WES project will not exceed any of the level limits the project will be considered to be within allowable limits for safety and health. If the Applicant submits only partial information required for this comparison the application cannot be approved. In all cases the burden to establish the operation as meeting safety and health limits will be on the Applicant.

Next, it covers requirements for the sound propagation model to be supplied with the application.

Finally, if the project is approved, this section covers the study needed to compare the post-build sound levels to the predictions and the baseline study. The level limits in the ordinance apply to the post-build study. In addition, if there have been any complaints about WES sound or low frequency noise emissions or wind turbine noise induced dwelling vibration by any resident of an occupied dwelling that property will be included in the post-build study for evaluation against the rules for sound level limits and compliance.

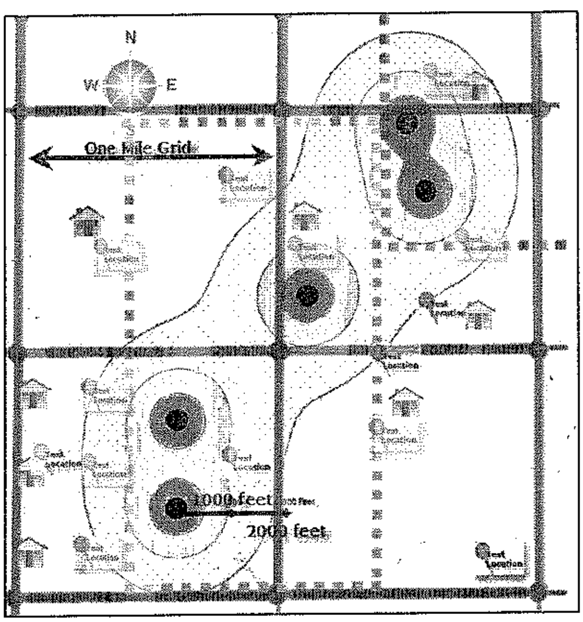
The characteristics of the proposed WES project and the features of the surrounding environment will influence the design of the sound and vibration study. Site layout, types of WES(s) selected and the existence of other significant local audible and low frequency sound sources and sensitive receptors should be taken into consideration when designing a sound study. The work will be performed by a qualified independent acoustical consultant for both the pre-construction background and post-construction sound studies as described in the body of the ordinance.

II. Instrumentation

All instruments and other tools used to measure audible, inaudible and low frequency sound shall meet the requirements for ANSI or IEC Type 1 Integrating Averaging Sound Level Meter Standards The principle standard reference for this document is ANSI 12.9/Part 3 with important additional specific requirements for the measuring instrumentation and measurement protocol.

III. Measurement of Pre-Construction Sound Environment (Base-line)

An assessment of the proposed WES project areas existing sound environment is necessary in order to predict the likely impact resulting from a proposed project. The following guidelines must be used in developing a reasonable estimate of an area's existing background sound environment. All testing is to be performed by an independent qualified acoustical consultant approved by the LGA as provided in the body of the ordinance. The WES applicant may file objections detailing any concerns it may have with the LGA's selection. These concerns will be addressed in the study. Objections must be filed prior to the start of the noise study. All measurements are to be conducted with ANSI or IEC Type 1 certified and calibrated test equipment per reference specification at the end of this section. Test results will be reported to the LGA or its appointed representative.



Sites with No Existing Wind Energy Systems (Base-line Sound Study)

Sound level measurements shall be taken as follows:

The results of the model showing the predicted worst case L_{Aeq} and L_{Ceq} sound emissions of the proposed WES project will be overlaid on a map (or separate L_{Aeq} and L_{Ceq} maps) of the project area. An example (right) shows an approximately two (2) mile square section with iso-level contour lines prepared by the applicant, sensitive receptors (homes) and locations selected for the baseline sound tests whichever are the controlling metric. The test points shall be located at the property line bounding the property of the turbine's host closest to the wind turbine. Additional sites may be added if appropriate. A grid comprised of one (1) mile boundaries (each grid cell is one (1) square mile) should be used to assist in identifying between two (2) to ten (10) measurement points per cell. The grid shall extend to a minimum of two (2) miles beyond the perimeter of the project boundary. This may be extended to more than two (2) miles at the discretion of the LGA. The measurement points shall be selected to represent the noise sensitive receptor sites based on the anticipated sound propagation from the combined WT in the project. Usually, this will be the closest WT. If there is more than one WT near-by then more than one test site may be required.

The intent is to anticipate the locations along the bounding property line that will receive the highest sound immissions. The site that will most likely be negatively affected by the WES project's sound emissions should be given first priority in testing. These sites may include sites adjacent to occupied dwellings or other noise sensitive receptor sites. Sites shall be selected to represent the locations where the background soundscapes reflect the quietest locations of the sensitive receptor sites. Background sound levels (and 1/3 octave band sound pressure levels if required) shall be obtained according to the definitions and procedures provided in the ordinance and recognized acoustical testing practice and standards.

All properties within the proposed WES project boundaries will be considered for this study.

One test shall be conducted during the period defined by the months of April through November with the preferred time being the months of June through August. These months are normally associated with more contact with the outdoors and when homes may have open windows during the evening and night. Unless directed otherwise by the LGA the season chosen for testing will represent the background soundscape for other seasons. At the discretion of the LGA, tests may be scheduled for other seasons.

All measurement points (MPs) shall be located with assistance from the LGA staff and property owner(s) and positioned such that no significant obstruction (building, trees, etc.) blocks sound and vibration from the nearest proposed WES site.

Duration of measurements shall be a minimum of ten (10) continuous minutes for all criteria at each location. The duration must include at least six (6) minutes that are not affected by transient sounds from near-by and non-nature sources. Multiple ten (10) minute samples over longer periods such as 30 minutes or one (1) hour may be used to improve the reliability of the L_{A90} and L_{C90} values. The ten (10) minute sample with the lowest valid L_{90} values will be used to define the background sound.

The tests at each site selected for this study shall be taken during the expected 'quietest period of the day or night' as appropriate for the site. For the purpose of determining background sound characteristics the preferred testing time is from 10pm until 4 am. If circumstances indicated that a different time of the day should be sampled the test may be conducted at the alternate time if approved by the Town.

Sound level measurements shall be made on a weekday of a non-holiday week. Weekend measurements may also be taken at selected sites where there are weekend activities that may be affected by WT sound.

Measurements must be taken with the microphone at 1.2 to 1.5 meters above the ground and at least 15 feet from any reflective surface following ANSI 12.9 Part 3 protocol including selected options and other requirements outlined later in this Section.

Reporting

1. For each Measurement Point and for each qualified measurement period, provide each of the following measurements:

a. L_{Aeq}, L_{A10}, and L_{A90}, and

b. L_{Ceq}, L_{C10}, and L_{C90}

2. A narrative description of any intermittent sounds registered during each measurement. This may be augmented with video and audio recordings.

3. A narrative description of the steady sounds that form the background soundscape. This may be augmented with video and audio recordings.

4. Wind speed and direction at the microphone (Measurement Point), humidity and temperature at time of measurement will be included in the documentation. Corresponding information from the nearest 10 meter weather reporting station shall also be obtained.

Measurements taken only when wind speeds are less than 2m/s (4.5 mph) at the microphone location will be considered valid for this study. A windscreen of the type recommended by the monitoring instrument's manufacturer must be used for all data collection.

5. Provide a map and/or diagram clearly showing (Using plot plan provided by LGA or Applicant):

- The layout of the project area, including topography, the project boundary lines, and property lines.
- The locations of the Measurement Points.
- The distance between any Measurement Points and the nearest WT(s).
- The location of significant local non-WES sound and vibration sources.
- The distance between all MPs and significant local sound sources. And,
- The location of all sensitive receptors including but not limited to: schools, day-care centers, hospitals, residences, residential neighborhoods, places of worship, and elderly care facilities.

Sites with Existing Wind Energy Systems

Two complete sets of sound level measurements must be taken as defined below:

1. One set of measurements with the wind generator(s) off unless the LGA elects to substitute the sound data collected for the background sound study. Wind speeds must be suitable for background sound tests as specified elsewhere in this ordinance.

2. One set of measurements with the wind generator(s) running with wind speed at hub height sufficient to meet nominal rated power output or higher and less than 2 m/s below at the microphone location. Conditions should reflect the worst case sound emissions from the WES project. This will normally involve tests taken during the evening or night when winds are calm (less than 2m/sec) at the ground surface yet, at hub height, sufficient to power the turbines.

Sound level measurements and meteorological conditions at the microphone shall be taken and documented as discussed above.

Sound level Estimate for Proposed Wind Energy Systems **(when adding more WT to existing project)**

In order to estimate the sound impact of the proposed WES project on the existing environment an estimate of the sound produced by the proposed WES(s) under worst-case conditions for producing sound emissions must be provided. This study may be conducted by a firm chosen by the WES operator with oversight provided by the LGA.

The qualifications of the firm should be presented along with details of the procedure that will be used, software applications, and any limitations to the software or prediction methods as required elsewhere in this ordinance for models.

Provide the manufacturer's sound power level (L_{Aw}) and (L_{Cw}) characteristics for the proposed WES(s) operating at full load utilizing the methodology in IEC 61400-11 Wind Turbine Noise Standard. Provide one-third octave band sound power level information from 6.3 Hz to 10k Hz. Furnish the data using no frequency weighting. A-weighted data is optional. Provide sound pressure levels predicted for the WES(s) in combination and at full operation and at maximum sound power output for all areas where the predictions indicate L_{Aeq} levels of 30 dBA and above. The same area shall be used for reporting the predicted L_{Ceq} levels. Contour lines shall be in increments of 5 dB.

Present tables with the predicted sound levels for the proposed WES(s) as L_{Aeq} and L_{Ceq} and at all octave band centers (8 Hz to 10k Hz) for distances of 500, 1000, 1500, 2000, 2500 and 5000 feet from the center of the area with the highest density of WES(s). For projects with multiple WES(s), the combined sound level impact for all WES(s) operating at full load must be estimated.

The above tables must include the impact (increased dBA and dBC (L_{eq}) above baseline L_{90} background sound levels) of the WES operations on all residential and other noise sensitive receiving locations within the project boundary. To the extent possible, the tables should include the sites tested (or likely to be tested) in the background study.

Provide a contour map of the expected sound level from the new WES(s), using 5dB L_{Aeq} and L_{Ceq} increments created by the proposed WES(s) extending out to a distance of two (2) miles from the project boundary, or other distance necessary, to show the 25 L_{Aeq} and 50 L_{Ceq} boundaries.

Provide a description of the impact of the proposed sound from the WES project on the existing environment. The results should anticipate the receptor sites that will be most negatively impacted by the WES project and to the extent possible provide data for each MP that are likely to be selected in the background sound study (note the sensitive receptor MPs):

1. Report expected changes to existing sound levels for L_{Aeq} and L_{A90}
2. Report expected changes to existing sound levels for L_{Ceq} and L_{C90}
3. Report the expected changes to existing sound pressure levels for each of the 1/1 or 1/3 octave bands in tabular form from 8 Hz to 10k Hz.
4. Report all assumptions made in arriving at the estimate of impact, any limitations that might cause the sound levels to exceed the values of the estimate, and any conclusions reached regarding the potential effects on people living near the project area. If the effects of coherence, worst case weather, or operating conditions are not reflected in the model a discussion of how these factors could increase the predicted values is required.
5. Include an estimate of the number of hours of operation expected from the proposed WES(s) and under what conditions the WES(s) would be expected to run. Any differences from the information filed with the Application should be addressed.

IV. Post-Construction Measurements

Post Construction Measurements should be conducted by a qualified noise consultant selected by and under the direction of the LGA. The requirements of this Appendix for Sites with Existing Wind Energy Systems shall apply

1. Within twelve months of the date when the project is fully operational, preferably within two weeks of the anniversary date of the pre-construction background sound measurements, repeat the measurements. Post-construction sound level measurements shall be taken both with all WES(s) running and with all WES(s) off except as provided in this ordinance.

2. Report post-construction measurements to the LGA using the same format as used for the background sound study.

VIII. REFERENCE Standards and ANSI S12.9 Part 3 with Required Amendments

ANSI/ASA S12.9-1993/Part 3 (R2008) - American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-Term Measurements with an Observer Present.

This standard is the second in a series of parts concerning description and measurement of outdoor environmental sound. The standard describes recommended procedures for measurement of short-term, time-average environmental sound outdoors at one or more locations in a community for environmental assessment or planning for compatible land uses and for other purposes such as demonstrating compliance with a regulation. These measurements are distinguished by the requirement to have an observer present. Sound may be produced by one or more separate, distributed sources of sound such as a highway, factory, or airport. Methods are given to correct the measured levels for the influence of background sound.

Wind Turbine Siting Acoustical Measurements
ANSI S12.9 Part 3 Selected Options and Requirement Amendments

For the purposes of this ordinance specific options provided in ANSI S12.9-Part 3 (2008) shall apply with the additional following requirements to Sections in ANSI S12.9/Part 3:

5.2 background sound: Use definition (1) 'long-term'
5.2 long-term background sound: The L_{90} excludes short term background sounds
5.3 basic measurement period: Ten (10) minutes $L_{90(10\ min)}$
5.6 Sound Measuring Instrument: Type 1 Integrating Meter meeting ANSI S1.43 or IEC 61672-1. The sound level meter shall cover the frequency range from 6.3 Hz to 20k Hz and simultaneously measure dBA L_N and dBC L_N. The instrument must also be capable of accurately measuring low-level background sounds down to 20 dBA.
6.5 Windscreen: Required
6.6(a) An anemometer accurate to ± 10% at 2m/s. to full scale accuracy. The anemometer shall be located 1.5 to 2m above the ground and orientated to record maximum wind velocity. The maximum wind velocity, wind direction, temperature and humidity shall be recorded for each ten (10) minute sound measurement period observed within 5 m. of the measuring microphone..
7.1 Long-term background sound
7.2 Data collection Methods: Second method with observed samples to avoid contamination by short term sounds (purpose: to avoid loss of statistical data)
8 Source(s) Data Collection: All requirements in ANSI S12.18 Method #2 precision to the extent possible while still permitting testing of the conditions that lead to complaints. The

meteorological requirements in ANSI S12.18 may not be applicable for some complaints. For sound measurements in response to a complaint, the compliance sound measurements should be made under conditions that replicate the conditions that caused the complaint without exceeding instrument and windscreen limits and tolerances.

8.1(b) Measuring microphone with windscreen shall be located 1.2m to 1.8m (1.5m preferred) above the ground and greater than 8m from large sound reflecting surface.

8.3(a) All meteorological observations required at both (not either) microphone and nearest 10m weather reporting station.

8.3(b) For a 10 minute background sound measurement to be valid the wind velocity shall be less then 2m/s (4.5 mph) measured less than 5m from the microphone. Compliance sound measurements shall be taken when winds shall be less than 4m/s at the microphone.

8.3(c) In addition to the required acoustic calibration checks, the sound measuring instrument internal noise floor, including microphone, must also be checked at the end of each series of ten minute measurements and no less frequently than once per day. Insert the microphone into the acoustic calibrator with the calibrator signal off. Record the observed dBA and dBC reading on the sound level meter to determine an approximation of the instrument self noise. Perform this test before leaving the background measurement location. This calibrator-covered microphone must demonstrate the results of this test are at least 5 dB below the immediately previous ten-minute acoustic test results, for the acoustic background data to be valid. This test is necessary to detect undesired increase in the microphone and sound level meter internal self-noise. As a precaution sound measuring instrumentation should be removed from any air-conditioned space at least an hour before use. Nighttime measurements are often performed very near the meteorological dew point. Minor moisture condensation inside a microphone or sound level meter can increase the instrument self noise and void the measured background data.

8.4 The remaining sections starting at 8.4 in ANSI S12.9 Part 3 Standard do not apply.

ANSI S12.18-1994 (R2004) American National Standard Procedures for Outdoor Measurement of Sound Pressure Level

This American National Standard describes procedures for the measurement of sound pressure levels in the outdoor environment, considering the effects of the ground, the effects of refraction due to wind and temperature gradients, and the effects due to turbulence. This standard is focused on measurement of sound pressure levels produced by specific sources outdoors. The measured sound pressure levels can be used to calculate sound pressure levels at other distances from the source or to extrapolate to other environmental conditions or to assess compliance with regulation. This standard describes two methods to measure sound pressure levels outdoors. METHOD No. 1: general method; outlines conditions for routine measurements. METHOD No. 2: precision method; describes strict conditions for more accurate measurements. This standard assumes the measurement of A-weighted sound pressure level or time-averaged sound pressure level or octave, 1/3-octave or narrow-band sound pressure level, but does not preclude determination of other sound descriptors.

ANSI S1.43-1997(R2007) American National Standard Specifications for Integrating Averaging Sound Level Meters

This Standard describes instruments for the measurement of frequency-weighted and time-average sound pressure levels. Optionally, sound exposure levels may be measured. This standard is consistent with the relevant requirements of ANSI S1.4-1983(R 1997) American National Standard Specification for Sound Level Meters, but specifies additional characteristics that are necessary to measure the time-average sound pressure level of steady, intermittent, fluctuating, and impulsive sounds.

ANSI S1.11-2004 American National Standard 'Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters'

This standard provides performance requirements for analog, sampled-data, and digital implementations of band-pass filters that comprise a filter set or spectrum analyzer for acoustical measurements. It supersedes ANSI S1.11-1986 (R1998) American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters, and is a counterpart to International Standard IEC 61260:1995 Electroacoustics - Octave-Band and Fractional-Octave-Band Filters. Significant changes from ANSI S1.11-1986 have been adopted in order to conform to most of the specifications of IEC 61260:1995. This standard differs from IEC 61260:1995 in three ways: (1) the test methods of IEC 61260 clauses 5 is moved to an informative annex, (2) the term 'band number,' not present in IEC 61260, is used as in ANSI S1.11-1986, (3) references to American National Standards are incorporated, and (4) minor editorial and style differences are incorporated.

ANSI S1.40-2006 American National Standard Specifications and Verification Procedures for Sound Calibrators

IEC 61400-11

Second edition 2002-12, Amendment 1 2006-05

IEC 61400-11

Second edition 2002-12, Amendment 1 2006-0

Wind turbine generator systems –Part 11: Acoustic noise measurement techniques

The purpose of this part of IEC 61400 is to provide a uniform methodology that will ensure consistency and accuracy in the measurement and analysis of acoustical emissions by wind turbine generator systems. The standard has been prepared with the anticipation that it would be applied by:

- the wind turbine manufacturer striving to meet well defined acoustic emission performance requirements and/or a possible declaration system;
- the wind turbine purchaser in specifying such performance requirements;
- the wind turbine operator who may be required to verify that stated, or required, acoustic performance specifications are met for new or refurbished units;
- the wind turbine planner or regulator who must be able to accurately and fairly define acoustical emission characteristics of a wind turbine in response to environmental regulations or permit requirements for new or modified installations.

This standard provides guidance in the measurement, analysis and reporting of complex acoustic emissions from wind turbine generator systems. The standard will benefit those parties involved in the manufacture, installation, planning and permitting, operation, utilization, and regulation of wind turbines. The measurement and analysis techniques recommended in this document should be applied by all parties to insure that continuing development and operation of wind turbines is carried out in an atmosphere of consistent and accurate communication relative to environmental concerns. This standard presents measurement and reporting procedures expected to provide accurate results that can be replicated by others.

End of Measurement Procedure

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VIII. Noise-Con 2008 Paper

Dearborn, Michigan

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Simple guidelines for siting wind turbines to prevent health risks[30]

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Revision: 2.1[31]

Industrial scale wind turbines are a familiar part of the landscape in Europe, U.K. and other parts of the world. In the U.S., however, similar industrial scale wind energy developments are just beginning operation. The presence of industrial wind projects will increase dramatically over the next few years given the push by the Federal and state governments to promote renewable energy sources through tax incentives and other forms of economic and political support. States and local governments in the U.S. are promoting what appear to be lenient rules for how industrial wind farms can be located in communities, which are predominantly rural and often very quiet. Studies already completed and currently in progress describe significant health effects associated with living in the vicinity of industrial grade wind turbines. This paper reviews sound studies conducted by consultants for governments, the wind turbine owner, or the local residents for a number of sites with known health or annoyance problems. The purpose is to determine if a set of simple guidelines using dBA and dBC sound levels can serve as the 'safe' siting guidelines. Findings of the review and recommendations for sound limits will be presented. A discussion of how the proposed limits would have affected the existing sites where people have demonstrated pathologies apparently related to wind turbine sound will also be presented.

Background

A relatively new source of community noise is spreading rapidly across the rural U.S. countryside. Industrial grade wind turbines, a common sight in many European countries, are now being promoted by Federal and state governments as the way to minimize coal powered electrical energy and its effects on global warming. But, the initial developments using the newer 1.5 to 3 MWatt wind turbines here in the U.S. has also led to numerous complaints from

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31 The criteria table at the end of this paper and portions of the narrative have been revised to reflect our current understanding of how to specify the sound limits with less ambiguity and to use the new format for presenting them.

residents who find themselves no longer in the quiet rural communities they were living in before the wind turbine developments went on-line. Questions have been raised about whether the current siting guidelines being used in the U.S. are sufficiently protective for the people living closest to the developments. Research being conducted into the health issues using data from established wind turbine developments is beginning to appear that supports the possibility there is a basis for the health concerns. Other research into the computer modeling and other methods used for determining the layout of the industrial wind turbine developments and the distances from residents in the adjacent communities are showing that the output of the models should not be considered accurate enough to be used as the sole basis for making the siting decisions.

The authors have reviewed a number of noise studies conducted in response to community complaints for wind energy systems sited in Europe, Canada, and the U.S. to determine if additional criteria are needed for establishing safe limits for industrial wind turbine sound immissions in rural communities. In several cases, the residents who filed the complaints have been included in studies by medical researchers who are investigating the potential health risks associated with living near industrial grade wind turbines 365 days a year. These studies were also reviewed by the authors to help in identifying what factors need to be considered in setting criteria for 'safe' sound limits at receiving properties. Due to concerns about medical privacy, details of these studies are not discussed in this paper. Current standards used in the U.S. and in most other parts of the world rely on not-to-exceed dBA sound levels, such as 50 dBA, or on not-to-exceed limits based on the pre-construction background sound level plus an adder (e.g. L_{90A} + 5 dBA).

Our review covered the community noise studies performed in response to complaints, research on health issues related to wind turbine noise, critiques of noise studies performed by consultants working for the wind developer, and research/technical papers on wind turbine sound immissions and related topics. The papers are listed in Tables 1-4.

Table 1-List of Studies Related to Complaints

Resource Systems Engineering, Sound Level Study – Ambient & Operations Sound Level Monitoring, Maine Department of Environmental Protection Order No. L-21635-26-A-N, June 2007
ESS Group, Inc., Draft Environmental Impact Statement For The Dutch Hill Wind Power Project – Town of Cohocton, NY, November 2006
David M. Hessler, Environmental Sound Survey and Noise Impact Assessment – Noble Wethersfield Wind park – Towns of Wethersfield and Eagle NY For: Noble Environmental Power, LLC January 2007
George Hessler, "Report Number 101006-1, Noise Assessment Jordanville Wind Power Project," October 2006
HGC Engineering, "Environmental Noise Assessment Pubnico Point Wind Farm, Nova Scotia, Natural Resources Canada Contract NRCAN-06-0046," August 23, 2006
John I. Walker, Sound Quality Monitoring, East Point, Prince Edward Island" by Jacques Whitford, Consultants for Prince Edward Island Energy Corporation, May 28, 2007

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Table 2- List of Studies related to Health

Nina Pierpont, "Wind Turbine Syndrome - Abstract" from draft article and personal conversations. www.ninapierpont.com
Nina Pierpont, "Letter from Dr. Pierpont to a resident of Ontario, Canada, re: Wind Turbine Syndrome," Autumn 2007
Amanda Harry, "Wind Turbine Noise and Health" (2007)
Barbara J. Frey and Peter J. Hadden, "Noise Radiation from Wind Turbines Installed Near Homes, Effects on Health" (2007)
Eja Pedersen, "Human response to wind turbine noise – Perception, annoyance and moderating factors, Occupational and Environmental Medicine," The Sahlgrenska Academy, Gotenborg 2007
Robin Phipps, "In the Matter of Moturimu Wind Farm Application, Palmerston North, Australia," March 2007
WHO European Centre for Environment and Health, Bonn Office, "Report on the third meeting on night noise guidelines," April 2005

Table 3-List of Studies that review Siting Impact Statements

Richard H. Bolton, "Evaluation of Environmental Noise Analysis for 'Jordanville Wind Power Project,'" December 14, 2006 Rev 3.
Clifford P. Schneider, "Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at the Maple Ridge Wind Power Facility," Lowville, NY – 2007

Table 4-List of Research and Technical papers included in review process

Anthony L. Rogers, James F. Manwell, Sally Wright, "Wind Turbine Acoustic Noise," Renewable Energy Research Laboratory, Dept. of ME and IE, U of Mass, Amherst, amended June 2006
ISO. 1996. Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation. International Organization of Standardization. ISO 9613-2. p. 18.
G.P. van den Berg, "The Sounds of High Winds – the effect of atmospheric stability on wind turbine sound and microphone noise," Ph.D. thesis, 2006
Fritz van den Berg, "Wind Profiles over Complex Terrain," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
William K. G. Palmer, "Uncloaking the Nature of Wind Turbines-Using the Science of Meteorology," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Soren Vase Legarth, "Auralization and Assessment of Annoyance from Wind Turbines," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Julian T. and Jane Davis, "Living with aerodynamic modulation, low frequency vibration

and sleep deprivation - how wind turbines inappropriately placed can act collectively and destroy rural quietitude," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
James D. Barnes, "A Variety of Wind Turbine Noise Regulations in the United States - 2007," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
M. Schwartz and D. Elliott, Wind Shear Characteristics at Central Plains Tall Towers, NREL 2006
IEC 61400 "Wind turbine generator systems, Part 11: Acoustic noise measurement techniques," rev:2002

Discussion

After reviewing the materials in the tables; we have arrived at our current understanding of wind turbine noise and its impact on the host community and its residents. The review showed that some residents living as far as 3 km (two (2) miles) from a wind farm complain of sleep disturbance from the noise. Many residents living one-tenth this distance (300 m. or 1000 feet) from a wind farm are experiencing major sleep disruption and other serious medical problems from nighttime wind turbine noise. The peculiar acoustic characteristics of wind turbine noise immissions cause the sounds heard at the receiving properties to be more annoying and troublesome than the more familiar noise from traffic and industrial factories. Limits used for these other community noise sources do not appear to be appropriate for siting industrial wind turbines. The residents who are annoyed by wind turbine noise complain of the approximately one (1) second repetitive swoosh-boom-swoosh-boom sound of the turbine blades and "low frequency" noise. It is not apparent to these authors whether the complaints that refer to "low frequency" noise are about the audible low frequency part of the swoosh-boom sound, the one hertz amplitude modulation of the swoosh-boom sound, or some combination of both acoustic phenomena.

To assist in understanding the issues at hand, the authors developed the 'conceptual' graph for industrial wind turbine sound shown in Figure 1. This graph shows the data from one of the complaint sites plotted against the sound immission spectra for a modern 2.5 MWatt wind turbine; Young's threshold of perception for the 10% most sensitive population (ISO 0266); and a spectrum obtained for a rural community during a three hour, 20 minute test from 11:45 pm until 3:05 am on a windless June evening in near Ubly, Michigan a quiet rural community located in central Huron County. (Also called: Michigan's "Thumb.") It is worth noting that this rural community demonstrates how quiet a rural community can be when located at a distance from industry, highways, and airport related noise emitters.

During our review we posed a number of questions to ourselves related to what we were learning. The questions (italics) and our answers are:

Do National or International or local community Noise Standards for siting wind turbines near dwellings address the low frequency portion of the wind turbine's sound immissions?[32] No! State and Local governments are in the process of establishing wind farm noise limits and/or wind turbine

[32] Emissions refer to acoustic energy from the 'viewpoint' of the sound emitter, while immissions refer to acoustic energy from the viewpoint of the receiver.

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setbacks from nearby residents, but the standards incorrectly presume that limits based on dBA levels are sufficient to protect the residents.

Do wind farm developers have noise limit criteria and/or wind turbine setback criteria that apply to nearby residents? Yes! But the Wind Industry recommended residential wind turbine noise levels (typically 50-55 dBA) are too high for the quiet nature of the rural communities and may be unsafe for the nearest residents. An additional concern is that some of the methods for implementing pre-construction computer models may predict sound levels that are too low. These two factors combined can lead to post-construction complaints and health risks.

Are all residents living near wind farms equally affected by wind turbine noise? No, children, people with pre-existing medical conditions, especially sleep disorders, and the elderly are generally the most susceptible. Some people are unaffected while some nearby neighbors develop serious health effects caused by exposure to the same wind turbine noise.

How does wind turbine noise impact nearby residents? Initially, the most common problem is chronic sleep deprivation during nighttime. According to the medical research documents, this may develop into far more serious physical and psychological problems

What are the technical options for reducing wind turbine noise immission at residences? There are only two options: 1) increase the distance between source and receiver, and/or 2) reduce the source sound power immission. Either solution is incompatible with the objective of the wind farm developer to maximize the wind power electrical generation within the land available.

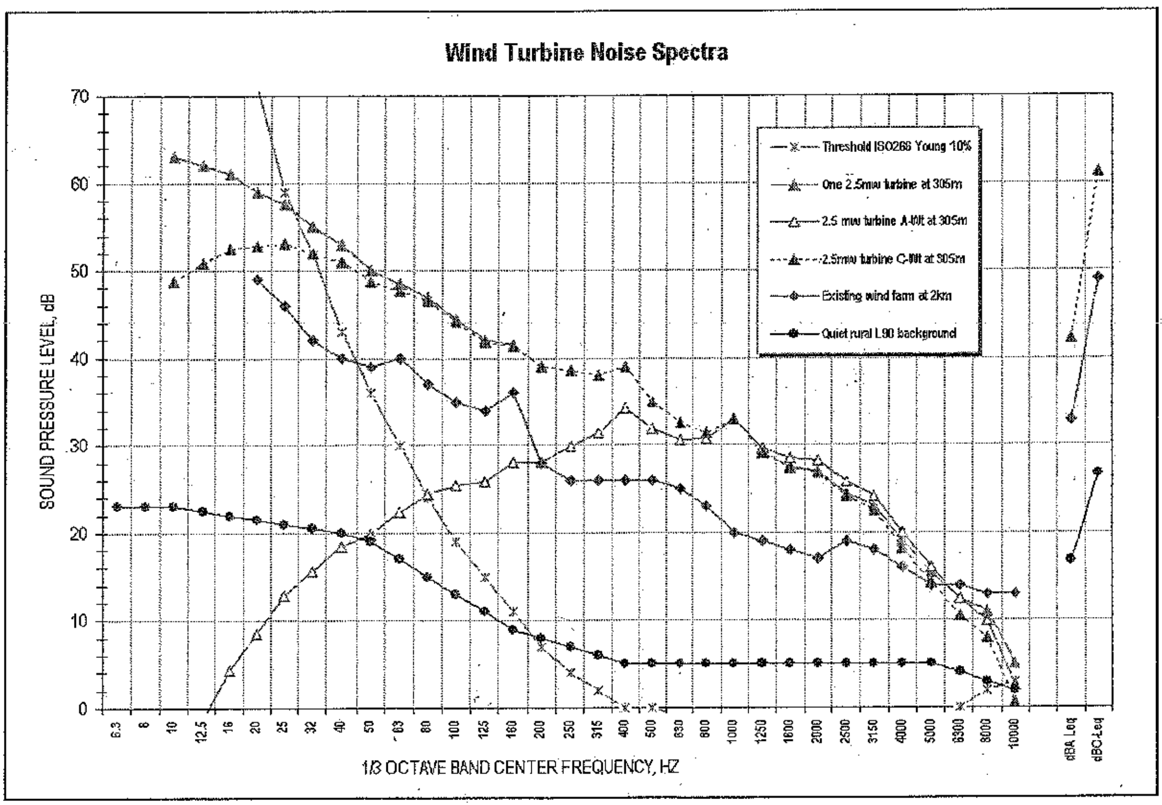

Figure 1-Generalized Sound Spectra vs. perception and rural community L_{90A} background 1/3 octave SPL

Is wind turbine noise at a residence much more annoying than traffic noise? Yes, researchers have found that "Wind turbine noise was perceived by about 85% of the respondents even when the calculated A-weighted SPL were as low as 35.0-37.5 dB. This could be due to the presence of amplitude modulation in the noise, making it easy to detect and difficult to mask by ambient noise." [JASA 116(6), December 2004, pgs 3460-3470, "Perception and annoyance due to wind turbine noise-a dose-relationship" Eja Pedersen and Kerstin Persson Waye, Dept of Environmental Medicine, Goteborg University, Sweden]

Why do wind turbine noise immissions of only 35 dBA disturb sleep at night? This issue is now being studied by the medical profession. The affected residents complain of the middle to high frequency swooshing sounds of the rotating turbine blades at a constant repetitive rate of about 1 hertz plus low frequency noise. The amplitude modulation of the swooshing sound changes continuously. The short time interval between the blade's swooshing sounds described by residents as sometimes having a thump or low frequency banging sound that varies in amplitude up to 10 dBA. This may be a result of phase changes between turbine emissions, turbulence, or an operational mode.. The assumptions about wall and window attenuation being 15 dBA or more may not be sufficiently protective considering the relatively high amplitude of the wind turbine's low frequency immission spectra.

What are the typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. Example criteria include: Australia-the lower of 35 dBA or L_{90} + 5 dBA, Denmark-40 dBA, France L_{90} + 3 (night) and L_{90} + 5 (day), Germany-40 dBA, Holland-40 dBA, United Kingdom-40 dBA (day) and 43 dBA (night) or L_{90} + 5 dBA, Illinois-55 dBA (day) and 51 dBA (night), Wisconsin-50 dBA and Michigan-55 dBA. Note: Illinois statewide limits are expressed only in nine contiguous octave frequency bands and no mention of A-weighting for the hourly L_{eq} limits. Typically, wind turbine noise just meeting the octave band limits would read 5 dB below the energy sum of the nine octave bands after applying A-weighting. So the Illinois limits are approximately 50 dBA (daytime 7 AM to 10 PM) and 46 dBA at night, assuming a wind farm is a Class C Property Line Noise Source.

What is a reasonable wind farm sound immission limit to protect the health of residences? We are proposing an immission limit of 35 dBA or L_{90A} + 5 dBA whichever is lower and also a C-weighted criteria to address the impacted resident's complaints of wind turbine low frequency noise: For the proposed criteria the dBC sound level at a receiving property shall not exceed L_{90A} + 20dB. In other words, the dBC operating immission limit shall not be more than 20 dB above the measured dBA (L_{90A}) pre-construction nighttime background sound level. A maximum not-to-exceed limit of 50 dBC is also proposed.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{90A}? The World Health Organization and others have determined a sound emitter's noise that results in a difference between the dBC and dBA value greater than 20 dB will be an annoying low frequency issue.

Is not L_{90A} the minimum dBA background noise level? This is not exactly correct. The L_{90} is the statistical descriptor representing the quietest 10% of the time. It may be understood as the sounds one hears when there are no nearby or short-term sounds from man-made or natural sources. It excludes sounds that are not part of the soundscape during all seasons. It is very important to establish the statistical average background noise environment outside a potentially impacted residence during the quietest (10 pm to 4 am) sleeping hours of the night. This nighttime sleep disturbance has generated the majority of the wind farm noise complaints throughout the world. The basis for a community's wind turbine sound immission limits would be the minimum 10 minute nighttime L_{90A} plus 5 dB for the time period of 10 pm to 7 am. This would become the Nighttime Immission Limits for the proposed wind farm. This can be accomplished with one or several ten (10) minute measurements during any night when the atmosphere is classified stable with a light wind from the area of the proposed wind farm. The Daytime Limits (7 am to 7 pm) could be set 10 dB above the minimum nighttime L_{90A} measured noise, but the nighttime criteria will always be the limiting sound levels.

A nearby wind farm meeting these noise immission criteria will be clearly audible to the residents occasionally during nighttime and daytime. Compliance with this noise standard would be determined by repeating the initial nighttime minimum nighttime L_{90A} tests and adding the dBC (L_{eqC}) noise measurement with the turbines on and off. If the nighttime background noise level (turbines off) was found to be slightly higher than the measured background prior to the wind farm installation, then the results with the turbines on must be corrected to determine compliance with the pre-turbine established sound limits.

The common method used for establishing the background sound level at a proposed wind farm used in many of the studies in Table 1 was to use unattended noise monitors to record hundreds of ten (10) minute measurements to obtain a statistically significant sample over varying wind conditions or a period of weeks. The measured results for daytime and nighttime are combined to determine the statically average wind noise as a function of wind velocity measured at a height of ten (10) meters. This provides an enormous amount of data but the results have little relationship to the wind turbine sound immission or turbine noise impact in nearby residents. The purpose of this exhaustive exercise often only demonstrates how much noise is generated by the wind. In some cases it appears that the data is used to 'prove' that the wind noise masks the turbine's sound immissions.

The most glaring failure of this argument occurs during the frequent nighttime condition of a stable atmosphere. Then, the wind turbines operate at full or near full power and noise output while the wind at ground level is calm and the background noise level is low. This is the condition of maximum turbine noise impact on nearby residents. It is the condition which most directly causes chronic sleep disruption. Furthermore, the measurement methodology is usually faulty, as much of the wind noise measured by unattended sound monitors is the pseudo-wind noise generated by failure of the microphone's windscreen. This results in totally erroneous background sound levels being used for permitting and siting decisions. (See studies in Table 3, esp. Van den Berg)

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes, The measuring sound level meter(s) need document the L_{Aeq}, L_{A10}, L_{A90} and L_{Ceq}, L_{C10}, L_{C90} sound levels plus start time & date for each 10 minute sample. The L_{10} results will be utilized to help validate that conditions were appropriate for measuring the L_{90} long term background sound levels. For example, on a quiet night one would expect L_{A10} to be less than 10 dB higher than the L_{A90} long-term background sound level. On a windy night or day the difference may be more than 20 dB. There is a requirement for measurement of the wind velocity near the sound measurement microphone continuously throughout each ten (10) minute recorded noise sample. The ten (10) minute average of the wind speed near the microphone shall not exceed 2 m/s (4.5 mph) and the maximum wind speed for operational tests shall not exceed 4 m/s (9 mph). It is strongly recommended that observed samples be used for these tests.

Is there a need to record weather data during the background noise recording survey? One weather monitor is required at the proposed wind farm on the side nearest the residents. The weather station sensors are at standard ten (10) meter height above ground. It is critical the weather be recorded every ten (10) minutes synchronized with the clocks in the sound level recorders without ambiguity in the start and end time of each ten (10) minute period. The weather station should record wind speed and direction, temperature, humidity and rain.

Why do Canada and some other countries base the permitted wind turbine noise immission limits on the operational wind velocity at the 10m height wind speed instead of a maximum dBA or L_{A90} *+ 5 dBA immission level?* First, it appears that the wind turbine industry will take advantage of every opportunity to elevate the maximum permitted noise immission level to reduce the setback distance from the nearby dwellings. Including wind as a masking source in the criteria is one method for elevating the permissible limits. Indeed the background noise level does increase with surface wind speed. When it does occur, it can be argued that the increased wind noise provides some masking of the wind farm turbine noise emission. However, in the middle of the night when the atmosphere is defined as stable (no vertical flow from surface heat radiation) the layers of the lower atmosphere can separate and permit wind velocities at the turbine hubs to be 2 to 4 times the wind velocity at the 10m high wind monitor but remain near calm at ground level. The result is the wind turbines can be operating at or close to full capacity while it is very quiet outside the nearby dwellings.

This is the heart of the wind turbine noise "problem" for residents within 3 km (approx. two miles) of a wind farm. When the turbines are producing the sound from operation it is quietest outside the surrounding homes. The PhD thesis of P.G. van den Berg "The Sounds of High Winds" is very enlightening on this issue. See also the letter by John Harrison in Ontario "On Wind Turbine Guidelines."

What sound monitor measurements would be needed for enforcement of the wind turbine sound ordinance? A similar sound and wind 10 minute series of measurements would be repeated at the pre-wind farm location nearest the resident registering the wind turbine noise complaint, with and without the operation of the wind turbines. An independent acoustics expert should be retained who reports to the County Board or other responsible governing body. This independent acoustics expert shall be responsible for all the acoustic measurements including instrumentation setup, calibration and interpretation of recorded results. An independent acoustical consultant shall also perform all pre-turbine background noise measurements and interpretation of results to establish the Nighttime (and Daytime if applicable) industrial wind turbine sound immission limits. At present the acoustical consultants are retained by, and work directly for, the wind farm developer.

This presents a serious problem with conflict of interest on the part of the consultant. The wind farm developer would like to show the significant amount of wind noise that is present to mask the sounds of the wind turbine immissions. The wind farm impacted community would like to know that wind turbine noise will be only barely perceptible and then only occasionally during the night or daytime.

Is frequency analysis required either during pre-wind farm background survey or for compliance measurements? Normally one-third octave or narrower band analysis would only be required if there is a complaint of tones immission from the wind farm.

Proposed Sound Limits

The simple fact that so many residents complain of low frequency noise from wind turbines is clear evidence that the single A-weighted (dBA) noise descriptor used in most jurisdictions for siting turbines is not adequate. The only other simple audio frequency weighting that is standardized and available on all sound level meters is C-weighting or dBC. A standard sound level meter set to measure dBA is increasingly less sensitive to low frequency below 500 Hz (one octave above middle-C). The same sound level meter set to measure dBC is equally sensitive to all frequencies above 32 Hz (lowest note on grand piano). It is well accepted that dBC readings

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are more predictive of perceptual loudness than dBA readings if low frequency sounds are significant.

We are proposing to use the commonly accepted dBA criteria that is based on the pre-existing background sound levels plus a 5 dB allowance for the wind turbine's immissions (e.g. L_{90A} +5) for the audible sounds from wind turbines. In addition, to address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC. The Proposed Sound Limits are presented in the text box at the end of this paper.

For the current industrial grade wind turbines in the 1.5 to 3 MWatt range, the addition of the dBC requirement will result in an increased distance between wind turbines and the nearby residents. For the generalized graphs shown in Figure 1, the distances would need to be approximately double the current distance. This will result in setbacks in the range of 1 km or greater for the current generation of wind turbines if they are to be located in rural areas where the L_{90A} background sound levels are 30 dBA or lower. When no man-made sounds are audible they can even be under 20 dBA. In areas with higher background sound levels, turbines could be located somewhat closer, but still at a distance greater than the 305 m (1000 ft.) or less setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

1. Establishing Long-Term Background Noise Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9, Part 3.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles.

c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured wind speed at the microphone does not exceed 2 m/s (4.5 mph).

d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC data includes L_{C90}, L_{C10}, and L_{Ceq}. The maximum wind speed at the microphone during the ten minutes, a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is oftener shall also be recorded. A ten (10) minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone did not exceed 2 m/s during the same ten (10) minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located so as to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-To-Exceed Property Line Sound Immission Limits [1]

Criteria	Condition	dBA	dBC
A	Immission above pre-construction background:	$L_{Aeq} = L_{A90} + 5$	$L_{Ceq} = L_{C90} + 5$
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance	L_{Ceq} (immission) minus (L_{A90} (background)+5) $\leq$ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB

Notes

1	Each Test is independent and exceedances of any test establishes non-compliance Sound "immission" is the wind turbine noise emission as received at a property
2	A "Quiet rural environment" is a location 2 miles from a state road or other major transportation artery without high traffic volume during otherwise quiet periods of the day or night.
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.

[1] Procedures provided in Section 7. Measurement Procedures (Appendix to Ordinance) of the most recent version of "**The How To Guide To Siting Wind Turbines To Prevent Health Risks From Sound**" by Kamperman and James apply to this table.

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing the Long-Term Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearer to the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9-Part 3 apply as amended. Instrumentation limits for wind and other factors must be recognized and followed.

The authors have based these criteria, procedures, and language on their current understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. However, use of the following, in part or total, by any party is strictly voluntary and the user assumes all risks. Please seek professional assistance in applying the recommendations of this document to any specific community or WES development.

Prepared for: Rufus Brown

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STATE OF MAINE
BOARD OF ENVIRONMENTAL PROTECTION

In Re:

RECORD HILL WIND, LLC	)	
Roxbury, Oxford County	)	**AFFIDAVIT OF**
RECORD HILL WIND PROJECT	)	**MICHAEL A. NISSENBAUM, M.D.**
L-24441-24-A-N (approval	)	
L-24441-TF-B-N (approval)	)	

I, Michael A. Nissenbaum, M.D., being first duly sworn, do depose and say as follows:

1. My name is Michael A. Nissenbaum, M.D. I am a graduate of University of Toronto Medical School with post graduate training at McGill University and the University of California. I am a specialist in diagnostic imaging, whose training and work involves developing and utilizing an understanding of the effects of energy deposition, including sound, on human tissues. I am a former Associate Director of MRI at a major Harvard hospital, a former faculty member (junior) at Harvard University, and a published author. A copy of my CV is attached to this Affidavit as *Exhibit A.*

2. I give this Affidavit in support of citizens of the Roxbury, Maine area who are requesting the Board of Environmental Protection ("BEP") to grant a hearing on the health effects of the proposed Record Hill Wind Project.

3. I developed an interest in the health effects of wind turbine projects after becoming aware of and investigating the wide spread and serious health effects suffered by most of the residents of Mars Hill, Maine who live in proximity to a linear arrangement of wind turbines comprising a ridgeline wind Industrial Wind Project. I am preparing a formal study, which includes a control group, on the subject for publication in a peer reviewed medical journal. The draft will be sent to the New England Journal of Medicine for consideration for publication.

I attach a slide show on the preliminary findings of my research project as *Exhibit B* to this Affidavit.

4. There are some differences in the Mars Hill Wind Project now operating and the proposed Record Hill Wind Project. However, there are also some similarities regarding the DEP assessments and permitting process applied which are generally acknowledged to have failed in Mars Hill, and yet were applied once again at Record Hill. It is my opinion that the BEP should hold a public hearing to examine the potential health effects of the Record Hill Wind Project given the potential seriousness of the health issues, and to ensure that an appropriately corrected modeling process (compared to the flawed model that was in fact used) is implemented to best predict the sound emissions that can be expected from the Record Hill Wind Project.

5. The Final Order in the Record Hill application states at page 10 that "Enrad stated that infrasound has been widely accepted to be of no concern below the common human perception threshold of tonal sounds." This statement is in error. **Infrasound has not been widely accepted to be of no concern other than by non-physicians doing work contracted by members of the Wind Industry, and some of the key non-physicians utilized by the Wind Industry have issued self conflicting and contradictory opinions on the issue. There has been no medical refutation of the potential negative health effects of infrasound emmited by Industrial Wind Turbines and the subject is at the least an open medical issue of concern warranting immediate investigation given the haste with which Industrial Wind Projects are being planned and established. There is additionally at this point a small body of unrefuted medical research indicating that there may be problems associated with infrasound. Regardless, there are clear issues relating to audible low frequency noise of a persistent, pulsatile nature such as created by Industrial Wind Turbines.**

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6. The Final Order in Record Hill at pg. 10 also states that "MCDC found no evidence in peer- reviewed medical and health effects from noise generated by wind turbines other than occasional reports of annoyances." **While the word 'annoyance' has been used in European studies relating to this turbine noise, the term has been misinterpreted by the Wind Industry and the Maine CDC to mean an inconsequential disturbance, whereas the authors , not being medical doctors, and not being native English speakers, did not describe the health significance or severity of the 'annoyance' in medical terms. A review of the Mars Hill and Ontario findings, however, indicates that this 'annoyance' is one of the root causes of the sleep disturbances and secondary negative health effects suffered by the residents of Mars Hill, Maine.**

7. Furthermore, and more significantly, the Maine CDC did not investigate the cluster of health complaints in Mars Hill for potential significance. Given that Mars Hill potentially represents a new negative health phenomenon resulting from the interaction of a ridge line source of Industrial Wind Turbines sited too close to human dwellings after faulty pre installation sound modeling, this represents a failure of the Maine CDC to comply with its mandate to investigate newly arising health issues to better understand them and propose solutions for mitigation and future prevention where required. **As such, any statements emanating from the Maine CDC on this subject must be viewed as being based on incomplete information, at this point in time.**

8. **Ex-Governor Angus King, a principal in the Record Hill Wind Project, has publicly admitted to mistakes made in Mars Hill. To the extent that these mistakes relate to faulty pre installation sound modeling, he should be expected to agree that the same modeling mistakes should not be repeated in Record Hill.**

9. Credible evidence of negative health effects from Industrial Wind Projects has been collected in Ontario, Canada by Robert McMurtry, M.D. My own preliminary but significant findings from Mars Hill, Maine and a draft of a potential landmark book, "Wind Turbine Syndrome" by Nina Pierpont, M.D.., and others, are also new sources of concern. Dr. Pierpont is an accomplished and well respected physician who is making significant contributions to the body of knowledge on the health impacts of wind turbines. Her basic premises have been well received by some of the foremost experts in the field of Otorhinolaryngology and Otology. I furthermore agree with her statements and recommendations at pages 11-12 of an excerpt of her Draft Report attached hereto as *Exhibit C.*

10. On Saturday, September 12, 2009, the Maine Medical Association passed a resolution, attached hereto as *Exhibit D,* expressing enough concern about the potential health effects of wind projects to urge caution and appropriate sensitivity in siting and permitting, as well as further studies on the subject.

11. This resolution was passed over the prior objections (to a similar resolution in an MMA subcommittee) of the Director of the Maine CDC. The Maine CDC Director's refusal to recognize even potential negative health effects of wind power projects, and her public statements urging the rapid establishment of Industrial Wind Projects in Maine seem to be at odds with the caution expressed by the wider medical community, as indicated by the attached Maine Medical Association resolution, and, as noted above, appears based upon erroneously interpreted and incomplete information.

12. Pending the use of more appropriately designed modeling studies, and the establishment of more appropriate regulations, the DEP and LURC should exercise more caution and deliberation prior to permitting additional IndustrialWind Projects, recognizing that

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there are still currently unknowns. The physical scale of the Industrial Wind Turbines used today is relatively new and we are only beginning to learn, as physicians, about the presence or absence of negative health effects that may result from poor siting decisions. In so doing, they will be better discharging their responsibility to protect the health and safety of Maine citizens.

13. I urge BEP to hold a public hearing on the appeal of the DEP Final Order for Record Hill on health effects of the approved Industrial Wind Project and, if that hearing is held, I will give testimony summarized in this Affidavit.

Dated: September 17, 2009

Michael A. Nissenbaum, M.D.

STATE OF MAINE
Aroostook, ss.

September 17, 2009

Personally appeared the above-named Michael Nissenbaum, M.D., and being sworn, made oath that the foregoing statements by him described are upon his own knowledge, information and belief and that, so far as upon information and belief, that he believes this information to be true.

Before me,

Sally Carrier

Notary Public/Attorney-at-Law
My commission expires:

SALLY CARRIER
Notary Public, Maine
My Commission Expires
February 1, 2014

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EXHIBIT

D

Maine Medical Association
Resolution RE: Wind Energy and Public Health

WHEREAS, proposals to locate and build wind energy facilities in the State have at times proven controversial, due to concerns regarding potential effects of such facilities on the public health, and

WHEREAS, the trade off between the public good of generating electricity and the adverse health effects warrant appropriate evidence-based scientific research, and

WHEREAS, assessing the potential health impact of wind turbines has been difficult to measure but if present would be of significant concern. This is especially apparent regarding the noise level and other noise characteristics specific to industrial wind turbines, and

WHEREAS, there is a need for modification of the State's regulatory process for siting wind energy developments to reduce the potential for controversy regarding siting of grid-scale wind energy development and to address health controversy with regulatory changes to include, but not limited to:

a) Refining certain procedures of the Maine Department of Environmental Protection and the Maine Land Use Regulation Commission to reflect scientific evidence regarding potential health effects, and to further explore such potential health effects;

b) Judging the effects of wind energy development on potential public health by avoiding unreasonable noise and shadow flicker effects, with development setbacks and incorporating upto date noise regulations specific for industrial wind turbines adequate to protect public health and safety.

THEREFORE BE IT RESOLVED that the Maine Medical Association work with health organizations and regulatory agencies to provide scientific information of known medical consequences of wind development in order to help safeguard human health and the environment.

AND BE IT FURTHER RESOLVED that the Maine Medical Association 1) work with other stakeholders to encourage performance of studies on health effects of wind turbine generation by independent qualified researchers at qualified research institutions; 2) ensure that physicians and patients alike are informed of evidence-based research results.